Technical Memorandum:

Delta Risk Management Strategy (DRMS) Phase 1

Topical Area:

Emergency Response and Repair

Draft 2

Prepared by:
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Prepared for:
California Department of Water Resources (DWR)

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URS

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Subject: Delta Risk Management Strategy
Phase 1 Draft 2 Technical Memorandum – Emergency Response and Repair

Dear Mr. Svetich,

Please find herewith a copy of the subject technical memorandum. Members of the Steering Committee's Technical Advisory Committee and agency staff have reviewed the draft technical memorandum, and this second draft addresses their comments.

This technical memorandum was prepared by Rick Rhoads, Ingrid Maloney, H. Frank Du, and Curtis Loeb (Moffat & Nichol). This technical memorandum was reviewed by Dr. Said Salah-Mars (URS) and Marty McCann (JBA). Internal peer review was provided in accordance with URS' quality assurance program, as outlined in the (DRMS) project management plan.

Sincerely,

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Topical Area: Emergency Response and Repair

Preamble

The Delta Risk Management Strategy (DRMS) project was authorized by DWR to perform a risk analysis of the Delta and Suisun Marsh (Phase 1) and to develop a set of improvement strategies to manage those risks (Phase 2) in response to Assembly Bill 1200 (Laird, Chaptered, September 2005). The Technical Memorandum (TM), is one of 12 TMs (2 topics are presented in one TM: hydrodynamics and water management) prepared for topical areas for Phase 1 of the DRMS project. The topical areas covered in the Phase 1 Risk Analysis include:

1. Geomorphology of the Delta and Suisun Marsh
2. Subsidence of the Delta and Suisun Marsh
3. Seismic Hazards of the Delta and Suisun Marsh
4. Global Warming Effects in the Delta and Suisun Marsh
5. Flood Hazard of the Delta and Suisun Marsh
6. Wind Wave Action of the Delta and Suisun Marsh
7. Levee Vulnerability of the Delta and Suisun Marsh
8. Emergency Response and Repair of the Delta and Suisun Marsh Levees
9. Hydrodynamics of the Delta and Suisun Marsh
10. Water Management and Operation of the Delta and Suisun Marsh
11. Ecological Impacts of the Delta and Suisun Marsh
12. Impact to Infrastructure of the Delta and Suisun Marsh
13. Economic Impacts of the Delta and Suisun Marsh

Note that the Hydrodynamics and Water Quality topical area was combined with the Water Management and Operations topical area because they needed to be considered together in developing the model of levee breach water impacts for the risk analysis. The resulting team is the Water Analysis Module (WAM) Team and this TM is the Water Analysis Module TM.

The work product described in these TMs will be used to develop the integrated risk analysis of the Delta and Suisun Marsh. The results of the integrated risk analysis will be presented in a technical report referred to as:

14. Risk Analysis – Report

The first draft of this report was made available to the DRMS Steering Committee in April 2007.

Assembly Bill 1200 amends Section 139.2 of the Water Code, to read, “The department shall evaluate the potential impacts on water supplies derived from the Sacramento-San Joaquin Delta based on 50-, 100-, and 200-year projections for each of the following possible impacts on the delta:

1. Subsidence.
2. Earthquakes.
3. Floods.
4. Changes in precipitation, temperature, and ocean levels.
5. A combination of the impacts specified in paragraphs (1) to (4) inclusive.”

In addition, Section 139.4 was amended to read: (a) The Department and the Department of Fish and Game shall determine the principal options for the delta. (b) The Department shall evaluate and comparatively rate each option determined in subdivision (a) for its ability to do the following:

1. Prevent the disruption of water supplies derived from the Sacramento-San Joaquin Delta.
2. Improve the quality of drinking water supplies derived from the delta.
3. Reduce the amount of salts contained in delta water and delivered to, and often retained in, our agricultural areas.
4. Maintain Delta water quality for Delta users.
5. Assist in preserving Delta lands.
6. Protect water rights of the “area of origin” and protect the environments of the Sacramento- San Joaquin river systems.
7. Protect highways, utility facilities, and other infrastructure located within the delta.
8. Preserve, protect, and improve Delta levees.…”

In meeting the requirements of AB 1200, the DRMS project is divided into two parts. Phase 1 involves the development and implementation of a risk analysis to evaluate the impacts to the Delta of various stressing events. In Phase 2 of the project, risk reduction and risk management strategies for long-term management of the Delta will be developed.

Definitions and Assumptions

During the Phase 1 study, the DRMS project team developed various predictive models of future stressing events and their consequences. These events and their consequences have been estimated using engineering and scientific tools readily available or based on a broad and current consensus among practitioners. Such events include the likely occurrence of future earthquakes of varying magnitude in the region, future rates of subsidence given continued farming practices, the likely magnitude and frequency of storm events, the potential effects of global warming (sea level rise, climate change, and temperature change) and their effects on the environment. Using the current state of knowledge, estimates of the likelihood of these events occurring can be made for the 50-, 100-, and 200-year projections with some confidence.

While estimating the likelihood of stressing events can generally be done using current technologies, estimating the consequences of these stressing events at future times is somewhat more difficult. Obviously, over the next 50, 100, and 200 years, the Delta will undergo changes that will affect what impact the stressing events will have. To assess those consequences, some assumptions about the future “look” of the Delta must be established.

To address the challenge of predicting impacts under changing conditions, DRMS adopted the approach of evaluating impacts absent changes in the Delta as a baseline.

This approach is referred to as the “business-as-usual” (BAU) scenario. Defining a business-as-usual Delta is required, since one of the objectives of this work is to estimate whether ‘business-as-usual’ is sustainable for the foreseeable future. Obviously changes from this baseline condition can occur; however, as a basis of comparison for risks and risk reduction measures, the BAU scenario serves as a consistent standard rather than as a “prediction of the future” and relies on existing agreements, policies, and practices to the extent possible.

In some cases, there are instances where procedures and policies may not exist to define standard emergency response procedure during a major (unprecedented) stressing event in the Delta or restoration guidelines after such a major event. In these cases, prioritization of action will be based on: (1) existing and expected future response resources, and (2) highest value recovery/restoration given available resources.

This study relies solely on available data. Because of the limited time to complete this work, no investigation or research were to be conducted to supplement the state of knowledge.

Perspective

The analysis results presented in this technical memorandum do not represent the full estimate of risk for the topic presented herein. The subject and results are expressed whenever possible in probabilistic terms to characterize the uncertainties and the random nature of the parameters that control the subject under consideration. The results are the expression of either the probable outcome of the hazards (earthquake, floods, climate change, subsidence, wind waves, and sunny day failures) or the conditional probability of the subject outcome (levee failures, emergency response, water management, hydrodynamic response of the Delta and Suisun Marsh, ecosystem response, and economic impacts) given the stressing events.

A full characterization of risk is presented in the Risk Analysis Report. In that report, the integration of the probable initiating events, the conditional probable response of the Delta levee system, and the expected probable consequences are integrated in the risk analysis module to develop a complete assessment of risk to the Delta and Suisun Marsh.

Consequently, the subject areas of the technical memoranda should be viewed as pieces contributing to the total risk, and their outcomes represent the input to the risk analysis module.

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List of Acronyms and Abbreviations

CEQA	California Environmental Quality Act
cfs	cubic feet per second
DRMS	Delta Risk Management Strategy
DWR	Department of Water Resources
ER&R	Emergency Response and Repair
Lb	breach length
NEPA	National Environmental Policy Act
SRRQ	San Rafael Rock Quarry
tpd	tons per day

1. Introduction

The Emergency Response and Repair (ER&R) model has been developed as part of the Delta Risk Management Strategy (DRMS) project. This technical memorandum describes the model, its objectives, assumptions and limitations, its required inputs, and the outputs that will be generated by the module.

2. Objective

The objective of the ER&R model is to estimate the time and material required, and the associated costs, to stabilize damaged levee sections, prevent further damage, close breaches and dewater flooded islands following an event. An event (or sequence) is defined as a flood, seismic, or other event that results in any number of levee breaches and/or damaged levee sections. The event's consequences in terms of levee damage and failures are evaluated as part of the DRMS risk analysis and are passed on to the ER&R module. The ER&R model must be applicable for the range of events/sequences that will be modeled in the DRMS study, while also considering the effect on emergency response capability resulting from flood fighting activities during the winter months.

Following an event, depending on the repair prioritization scheme, breaches may be capped and/or filled, while damaged levee sections require remediation to prevent further breaches. In the case of flooded islands, where levees have been breached, the interior slope of damaged or intact sections of levees may be protected against erosion resulting from exposure to wind-driven wave action. Flooded islands may be dewatered after breach closure.

The ER&R model focuses on post-event actions only. Seasonal flood-fighting activities are not explicitly modeled, though the model allows for a reduction in emergency response capacity during the time of the year when one would expect non-event-related flood-fighting actions on non-flooded islands to be ongoing. As such, these activities would detract resources from the emergency operations.

3. Assumptions and Limitations

3.1 Business as Usual

It is assumed that rock placement will be exclusively utilized as the means of stabilizing damaged levees and breaches. It is also assumed that the normative approach used in the past will be followed. This normative approach includes capping of breach ends to stabilize the breach before attempts are made to close it, as well as placement of erosion protection on the interior levee slopes of flooded islands. Deviation from the normative approach is possible and, depending on the repair prioritization scheme, not all or any of these measures may be carried out on a particular island.

3.2 Material Source

It is assumed that the San Rafael Rock Quarry (SRRQ) is the primary source of material and the only source of material for marine-based activities. Currently, the SRRQ, located in San Rafael, California, and owned by The Dutra Group, is the primary supplier of quarry products for the Delta. The SRRQ is the only quarry located in northern California with direct loading access to barges. Consequently, the quarry possesses a significant advantage over competing quarries in its ability to directly load barges with product for delivery to the Delta and the economy of scale this advantage offers. Placement of erosion protection and repair of erosion damage can be carried out from land, if access permits. In this case, material is sourced from local quarries.

3.3 Applicability to Years 2050, 2100, and 2200

It is assumed that the SRRQ will be in operation for the next 200 years even though the quarry's rock supply is more consistent with approximately 52-years of continued operation.

3.4 Emergency Preparedness

The State has improved its pre-event emergency preparedness, and will likely continue such improvements as a result of lessons learned from the recent Jones Tract levee breach, as well as the findings of the DRMS. However, it is believed such measures will have a limited effect on overall emergency response and repair durations calculated by this model, since this model already presumes an effective emergency preparedness status is in place. Furthermore, as the magnitude of sequence damage increases, it is believed the effect of emergency preparedness on overall repair durations diminishes. Therefore, the model does not quantitatively account for such emergency preparedness preparations beyond the assumption that such preparations enable the model to meet the emergency response and repair production rates presumed within.

3.5 Operability after a Seismic Event

The SRRQ as well as all other infrastructure will remain operational after a seismic event. For instance, after a seismic event in the Bay Area, there may be access constraints for the barges if bridges have collapsed, but it has been assumed that there will be no access constraints.

3.6 Other Assumptions

- Within days of a sequence of levee breaches, local regulations will be eased or set aside to allow the SRRQ to operate on a 24-hour basis.
- Sufficient transportation equipment (i.e., deck barges, scows, and tugs) can be made available immediately, so that material supply capacity remains the constraint.
- Resources (i.e., materials and equipment) are assumed to be available and will not be compromised by demands outside the Delta that occur as a result of the same seismic event. Damage which occurs to assets other than levees will not put a demand on resources required to support levee breach repairs.
- Additional damage resulting from earthquake after-shocks is not considered.
- There are no constraints on dewatering resources.

The following factors are not explicitly accounted for in the emergency response and repair model, yet they may impact the results of the analysis:

- The time required to put contracts into place may be significant and will vary from event to event.
- It may not be possible for The Dutra Group to obtain permits to build a second loading facility in within 90 days. State/Federal officials may need to step in to waive the typical permitting process (California Environmental Quality Act [CEQA]/National Environmental Policy Act [NEPA]). Additionally, SRRQ neighbors may hold up the process if they do not see events in the Delta as an impact on them.
- It may take longer than 180 days to bring other sources of material on line. The State will probably have to make the decision when to call in help from non-local sources, such as Catalina Island, Canada, or Mexico.
- After a seismic event there may be numerous projects that will be competing for the same resources. The State may have to make the call on prioritization of competing projects.

4. Emergency Response and Repair Model

The model for the emergency response and repair for the Delta Risk Management Strategy is summarized in this section.

4.1 General

4.1.1 Event-Related Response and Repair

As part of the DRMS study, a risk model is being developed which will model the potential occurrence of events (floods, earthquakes, etc.) that may lead to levee failures and/or damaged levee segments. The risk model will consider the complete set of levee damage and/or failure sequences that could occur and their likelihood of occurrence.

Following an event, there may be a number of islands that are flooded as a result of one or more levee breaches on that island. In addition to levee breaches, there may be sections of the levee that have been damaged, but which have not been breached. A non-flooded island is one that does not experience a levee breach following an event. However, there may be sections of the levee that have been damaged, which require remediation in order to avoid a breach at a later time. Furthermore, each island that is flooded is susceptible to interior levee slope erosion resulting from exposure to wind-driven wave action. Erosion may occur on damaged or non-damaged sections of the levee. Erosion rates depend on the wind vulnerability of a particular section (“segment”) of levee, which is based on the fetch and exposure of that particular section of levee to the predominant wind direction.

Given a sequence that identifies a set of levee breaches and/or damage throughout the Delta, the ER&R model makes an assessment of the ability to respond. The assessment will address the following factors key to estimating the amount of time required for achieving a return to normal operations (i.e., normal water export):

- Prevention of continuing damage (remediation of damaged sections of levee, capping of breached levee ends, and interior levee protection)
- Breach closure
- Dewatering of flooded islands

The analysis considers gross quantities of material required for repairing damage and closing breaches and does not differentiate between material types.

4.1.2 Non-Event-Related Response and Repair

Depending on the time of year, there may be other flood fighting activities taking place in the Delta, which are not related to an event. These activities may detract resources from the event-related response activities.

4.2 Simulation Tool

The emergency response and repair module was developed as a simulation model, using the simulation software package Extend^{TM}, which is an industry-standard, general-purpose simulation tool that can be used to model a large variety of processes. Extend^{TM} is a powerful object-oriented simulation tool that uses the MOD-L programming language. This tool has been employed on many projects that required probabilistic assessment to determine the risk/probability of outcomes.

The model employs Extend’s capability of combining discrete event simulation with continuous simulation flow architecture. In the discrete event simulation items are generated, each item representing a specific repair that must be carried out for the particular sequence being analyzed. The number of items required for a particular sequence depends on the number of individual breaches and damaged sections on the affected islands plus all eight levee segments on flooded islands that are susceptible to interior slope erosion, and the repair work order that has been specified for that sequence. The flow architecture in Extend is used to model the production rates, which represent the combination of production capacity of the quarries and transportation capability.

The emergency response and repair simulation model consists of a number of blocks. The main blocks are:

- Model Database
- Read and Organize Input Data
- Set up Simulation Items to Track Each Type of Repair Item
- Continuing Damage
- SRRQ Rock Supply
- Delta Quarries Rock Supply
- Ongoing Flood-Fighting Activities
- Repairs
- Dewatering

- Cost
- Output to Water Quality Model

4.3 Model Database

The model database consists of the Main Database and the Damage and Repair Progression Database.

The Main Database includes the main parameters associated with each island in the legal Delta and Suisun Marsh. The islands and their IDs match those from the URS GIS Database. Each island is divided into eight sectors corresponding to the eight compass directions (N, NE, E, SE, S, SW, W, and NW), as shown on Figure 4-1 and summarized in Table 4-1. The database includes levee cross sectional parameters, perimeter length, and fetch associated with each of the 8 segments of the island.

Table 4-1 Island Sectors

N	0	337.5 < θ <= 360, 0< θ <= 22.5
NE	45	22.5< θ <= 67.5
E	90	67.5< θ <= 112.5
SE	135	112.5< θ <= 157.5
S	180	157.5< θ <= 202.5
SW	225	202.5< θ <= 247.5
W	270	247.5< θ <= 292.5
NW	315	292.5< θ <= 337.5

The user input related to the sequence is processed and summarized in the Continuing Damage and Repair Progression Database. The database stores all the damage information related to the sequence. The database is updated to record changes to damaged volume, breach length, and damage status as time progresses, resulting from continuing damage and repair activities. Damage continues on each breach in accordance with the input breach growth rate, and on each damaged or intact levee located on a flooded island in accordance with erosion rates, as long as repair works have not been initiated on that particular section of the levee. As soon as capping of breach ends is commenced, the breach growth rate is set to zero; and as soon as repair starts on a damaged levee segment on a flooded island, the erosion rate is set to zero.

The database stores the priorities for each of the repairs, which are computed according to the preferences input by the user for that sequence. The start and end times of each of the repairs are recorded as they occur, as well as the quantity of rock placed, volume of water pumped, and associated cost. These parameters are recorded for each island segment and the island as a whole.

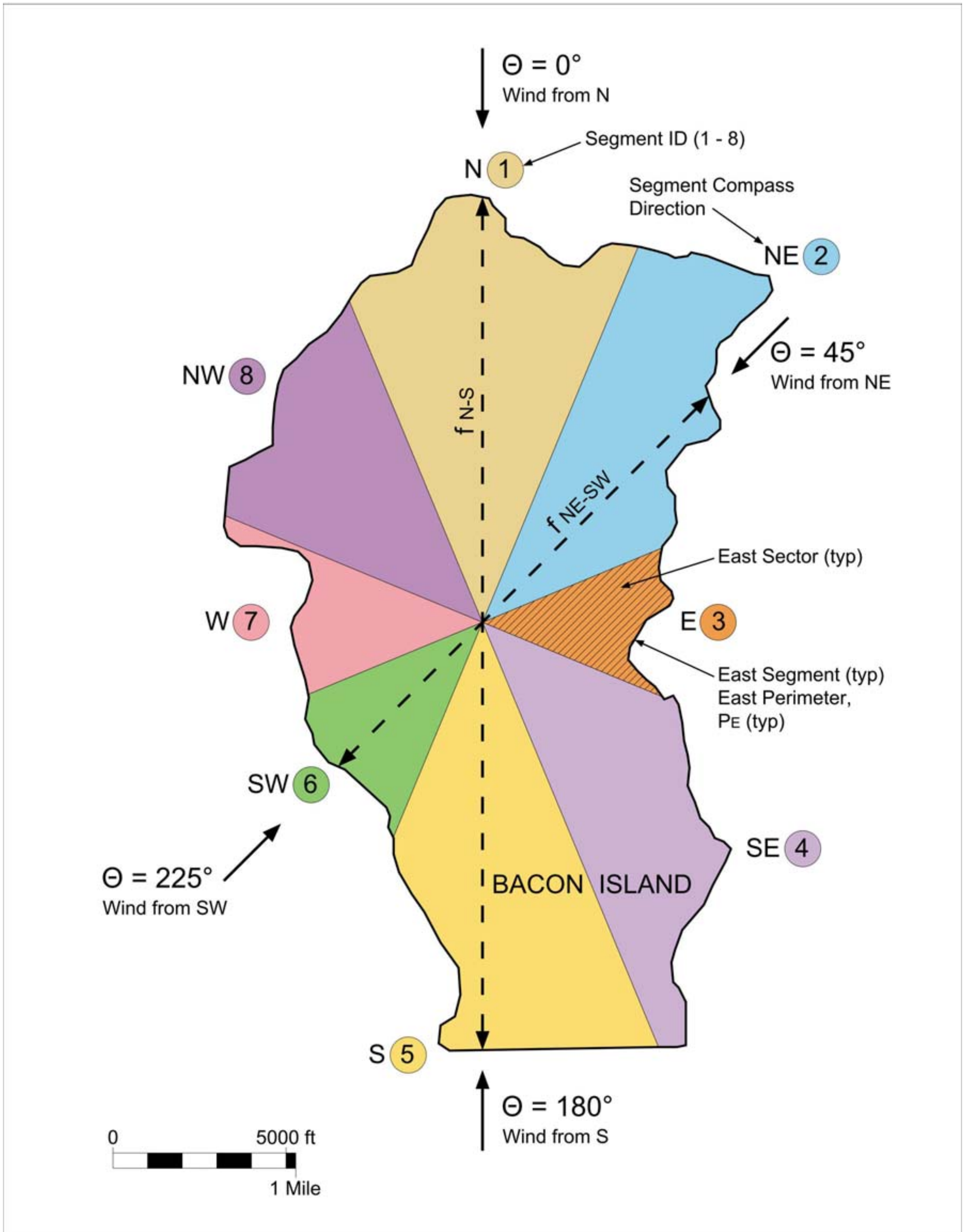

Figure 4-1 Division of Each Island into Eight Sectors

4.4 Repair Types

There are six repair types:

- RT1 repair post-event, non-breach damage on non-flooded island
- RT2 protect the levee interior slopes on a flooded island against wind wave damage, or repair of damage if it has already occurred
- RT3 repair post-event, non-breach damage on flooded island
- RT4 stabilize breached levees by capping the levee ends at the breach
- RT5 breach closure
- RT6 island dewatering

During the dry season, erosion protection and/or repair of damage resulting from erosion (repair type RT2) can be carried out from land, with rock produced at local quarries transported and dumped onto the interior slope by truck. This repair action is limited to those levees that have road access. Although the model differentiates between those islands that have land access and those that do not, it does not differentiate between roads that are in good condition and those that require strengthening to allow the land-based work to proceed. Resource and time requirements to strengthen or construct access roads to allow the truck transit associated with land-based repair are not included in the material, cost, and time estimates produced by the ER&R model. Furthermore, the model does not include any temporary or permanent raising of the levee elevation in the case of erosion protection or repair.

As mentioned in Section 2, the response and repair actions included in the ER&R model represent post-event actions only. Seasonal flood-fighting activities are not modeled, though the model allows for a reduction in emergency response capacity during the time of the year when non-event-related flood-fighting actions on non-flooded islands might be ongoing.

4.5 Island and Work Type Prioritization (Work Order)

A significant level of flexibility is provided in the ER&R model in terms of developing the repair program (work order) for a given sequence. This level of flexibility allows for complete definition of a work order to the point where the order of completion of tasks is defined across islands and repair types. The module provides a level of flexibility that is consistent with the level of flexibility that can practically be defined and implemented in the field.

Islands that are identified in a sequence as having been breached and or damaged are put into priority groups. The islands within a priority group have the same priority and the same repair work order. There can be as few as one group (all islands have equal priority and the same repair work order) or there can be as many groups as there are combinations of number of islands and repair work order. This scheme allows the user to completely define the work order, and to drop certain repair types, if desired.

4.6 Sequence Definition / User Input

The required user input is provided as three separate tables, similar to Tables 4-2, 4-3, and 4-4, which were generated for a randomly selected sequence.

4.6.1 Sequence Description

The first table defines a sequence, in terms of the number and lengths of the breaches and damaged sections. Levee segments are defined in order to facilitate identification of levee damage and susceptibility to erosion. For each island a geometrical center was determined and lines drawn from this center at equal angles to delineate eight sectors: N, NE, E, SE, S, SW, W, and NW (Figure 4-1). The levee segments are the perimeters of each of these eight sectors.

The first row of Table 4-2 gives the sequence ID and the day of the year (1 through 365) on which the event occurs. Damage is defined in the successive rows of the table by providing the island ID, the segment number (1 through 8), and the damage state (1=damaged, 2=breached) for each sector of a levee that sustains damage in the event. The length of the damaged (or breached) section, and slump height (or breach growth rate), are also defined. The time at which the breach occurs is given, providing a means for entering the possibility of a secondary breach occurring on a damaged section of levee.

Table 4-2 Sequence Description (Initial Breaches and Damages)

Sequence Id	Day Of Year				
8110	**0**				
Island Id	**Segment**	**Damage State (1)**	**Length (2)**	**Slump Height / Breach Growth Rate (3)**	**Time (Days)**
3	8	2	300	4	0
10	2	1	500	36	0
2	3	2	175	4	0
8	1	1	675	30	0
8	1	1	350	30	0
7	6	1	800	42	0
20	4	2	150	4	0
20	5	2	225	4	0
5	5	2	250	4	0
10	1	1	425	30	0
20	6	1	600	24	0
8	2	1	100	30	0
10	2	2	100	4	120

(1) damage state=1 means non-breach damage, damage state=2 means breach
(2) length = damage length or breach length (ft) depending on damage state
(3) slump height (in) or breach growth rate (in/day) depending on damage state
Flooded islands are shown shaded (typical all tables). Island 10 is shown as a non-flooded island, as this is the initial condition. At 120 days part of the damaged section on segment 2 breaches, flooding the island (provided the damage has not been fixed by that time).

The data in Table 4-2 can be listed in any order (i.e., the order does not need to be consecutive island order). An island may be listed multiple times in the case of multiple breaches and/or damaged levee sections along one or more of the levee's eight segments. The multiple occurrences of an island do not have to be listed in consecutive order.

4.6.2 Island Prioritization

Island priority groups are defined in order to allow for variations in work order prioritization among all the affected islands, while also allowing assignment of identical work order prioritization for similar islands. The island prioritization is defined for each sequence, although it may be likely that it will be identical for many, if not all, sequences.

Table 4-3 Assignment of Islands to Island Priority Groups

Sequence Id	
8110	
Island Id	**Island Priority Group**
3	1
2	3
5	2
7	2
8	1
10	1
20	2

In this example there are three priority groups. Priority group 1 (highest priority) includes non-flooded and flooded islands. So does priority group 2 (medium priority). Priority group 3 (lowest priority) includes only one flooded island. The islands can be listed in any order in Table 4-3, but they may be listed only once and <u>only those islands that are affected in the current sequence should be listed in Table 4-3</u>

There is no significance to the order in which islands are listed in Tables 4-2 and 4-3. Because this sequence is the current test case for the model, a completely random listing was chosen to demonstrate the generality of the model.

4.6.3 Repair Work Order / Prioritization

The prescribed order of carrying out the repair types RT1 through RT6 is defined for each island priority group via the input format of Table 4-4.

Table 4-4 Priorities for Repair of Initial Breaches and Damages

Sequence Id						
8110						
Island Priority Group	**RT1**	**RT2**	**RT3**	**RT4**	**RT5**	**RT6**
1	1	2	2	2	3	1
2	1	0 (1)	4	0	5	2
3	1	0	7	6	6	0

(1) opt not to protect interior slopes or to cap breaches on islands in Group 2 and opt not to protect interior slopes on islands in Group 3.

Priorities in Table 4-4 are defined by the user across island priority groups and across repair types. This allows for any work order within an island priority group or across all damaged islands. In this example, RT1 is to be completed on all damaged, non-flooded islands (starting with the islands in the highest priority group) before completing any other repairs. Repetition of a priority number implies that the repair type with the identical priority number should be completed on each island before moving on to the next island within the island's priority group. In the example, the second priority is to complete RT2-RT3-RT4 on island 3, then to do the same on island 8 and then on island 10 (it happens that both islands 8 and 10 are non-flooded and that they do not require repair types RT2, RT3 or RT4). Then RT5 is to be completed on island 3, followed by islands 8 and 10 (which do not require RT5, but if they did, they would be completed next).

Repair type RT6 (dewater island) is not part of the overall work order scheme as described above, but the entries in the column associated with RT6 allow the user to make the following decision for each island priority group:

> 0 = island not to be dewatered (even when breaches have been fixed).
> 1 = island to be dewatered as soon as all breaches have been fixed on the island, with the possibility that other, specified repairs may not have been completed.
> 2 = island to be dewatered only after all specified repairs have been completed on the island.

4.6.4 Internal Ordering of Repair Types

Internally, the three sets of input presented in Tables 4-2 through 4-4 are converted into a matrix as shown in Table 4-5. The accumulated length of damages and breaches on each island is computed and listed as it plays a factor in the prioritization. This is because the grouping of islands into priority groups does not provide any detail on the order in which islands are to be completed within a group. Within a priority group, islands are selected based on amount (lineal feet) of damage, with the least damaged island being repaired first.

If resources allow, repair types RT2, RT3 and RT4 can be implemented simultaneously on a given island. Repair type RT5 can only commence once RT4 is completed. Selected repair types can be deleted from the work order for one, several, or all island priority groups.

Table 4-5 Internal Ordering of Input Data

Island	Priority Group	Row # In Damage Array	Cumulative Damaged Length (feet)	RT1	RT2	RT3	RT4	RT5
3	1	1	300	0	2001012	0	2001014	3001015
2	3	10	175	0	0	0	6003074	6003075
5	2	19	250	0	0	0	0	5002045
7	2	28	800	1002051	0	0	0	0
8	1	37	1125	1001031	0	0	0	0
10	1	46	1025	1001021	2001022	2001023	2001024	3001025
20	2	55	975	0	0	4002063	0	5002065

4.7 Secondary Breaches on Non-Flooded Islands

Non-flooded islands may have (1) intact levee sections and/or (2) damaged (slumped) levee sections. Intact levee sections are assumed to remain intact throughout the repair period that is simulated in the ER&R module. However, damaged sections can breach as a result of a storm event that causes overtopping and subsequent breach.

The levee fragility model estimates the fragility of damaged levee exteriors to wind waves or high flow rates. The occurrence of a secondary breach will be input to the ER&R model as part of the sequence definition (Table 4-2). The secondary breach must be defined by the same parameters that are required for initial breaches, including breach length (Lb) and breach growth rate. The time at which the secondary breach occurs must also be defined; thus, secondary breaches are identified by the last column in Table 4-2, where T>0 days. The breach will only actually occur if the damaged levee segment has not been repaired at that point in time.

4.8 Continuing Damage on Flooded Islands

Flooded islands have either (1) intact levee sections, (2) damaged (slumped) levee sections, or (3) breached sections, as well as exposed levee interiors of intact or damaged sections.

4.8.1 Exterior Damage

In the case of slumped levee sections on a flooded island, overtopping from the exterior (from an episodic storm) will not result in further breaches, since there are equal heights of water on both sides of the levee. However, exterior damage could occur as a result of waves breaking on the crest instead of on the rip rap, as a result of an exterior episodic event. This would be an eroding type of damage (similar to interior slope erosion) over a short period of time, since it is episodic. Thus it is likely to not be an important factor (it adds a little more to the material requirement of the already damaged levee section. This type of damage could be added during a second phase of the project.

4.8.2 Breach Growth

Breached sections will grow in length over time. The user inputs (via Table 4-2) the mean growth rate. The breach growth that occurs after the island has flooded/equalized will be modeled as random, lognormally distributed with a mean and standard deviation equal to 10% of the mean value.

4.8.3 Wind Wave Erosion

Wind wave erosion on the levee’s interior slopes will act on the intact and damaged levee sections throughout the repair period that is simulated in the ER&R module. This erosion manifests itself as additional (continuing) damage on initially intact and damaged levee sections of flooded islands, resulting in larger quantities of rock required when the repair of that section proceeds.

Levee interior slope erosion is modeled as follows:

- Sets of erosion curves, or parametric equations, (time vs. erosion) are defined within the ER&R module for each island sector. The development of the wind wave erosion curves is presented in Appendix A.
- With each day that passes following flooding of the island, erosion damage is accumulated on the intact and damaged levee sections of each island sector.
- Erosion occurs at an equal rate along the entire levee perimeter of each island sector.
- The additional erosion acts on the levee width at MHHW (which is different for intact vs. damaged/slumped levee sections). When the levee's width has been eroded down to a threshold level of 6 feet (to be confirmed), it is assumed that the remaining portion of the levee fails, and the entire levee cross section above MLLW collapses and must be replaced for that specific levee segment.
- Accumulation of erosion damage stops when failure as defined above occurs or when laying of rock for protection of the levee interior is commenced. The amount of rock laid will be based on the amount required for the layer of protection plus the amount required to replace the eroded section that has been accumulated to that point.

4.9 Repair Rates

Since the rate of material supply is anticipated to be the governing constraint, the production rates (i.e., repair rates) are typically equal to the material loading rates.

Two potential sources of rock material are modeled. The SRRQ is assumed to be the primary source of material for all marine-based activities, which includes all the repair types identified in Section 4.4. The second source of rock is comprised of the numerous quarries in proximity of the Delta. The rock produced at these quarries is transported via truck; thus, use of local quarry rock is limited to the dry season and limited to those levees that have road access. Local quarry rock is used only for erosion protection and/or repair of damage resulting from erosion (repair type RT2).

It is assumed that one-half day will lapse before the contractor arrives at the initial levee failure and commences repair work. It is further assumed that another 2.5 days will lapse during which contracts for levee repair are put in place, although it is assumed that the contractor will start repair work during this period. Tables 4-6 and 4-7 summarize the assumed production rates by time at the SRRQ and at other quarries local to the Delta. Table 4-8 summarizes the production rates by activity for each phase of the repair and breach closure process. It is important to note that during a multi-damage and/or multi-breach sequence the maximum production rates will be limited by the material supply rates stated in Tables 4-6 and 4-7 in combination with the possible placing rates stated in Table 4-8; however, the priority for repairing damage, protecting interior slopes versus capping levee ends and closing breaches must be specified in order to properly allocate the fixed resource of material supply.

For interior levee wind/wave protection efforts, depending on access to the flooded island, material may be sourced from quarries other than the SRRQ and delivered by truck. There are three significant constraints that might prohibit this: 1) if there is no vehicular bridge access to the island, trucking will not be possible; 2) during periods of elevated water levels in the Delta (December through May), the operation of trucks on levees is prohibited owing to concerns related to the potential for damage to the levees caused by heavy truck traffic; 3) when more than one section of levee is damaged or breached, truck access is assumed not possible.

Material supply varies over time as more equipment and infrastructure is added in response to the emergency. Tables 4-6 and 4-7 present the assumed increase in production rates over time for the SRRQ and local quarries, respectively. The production rates quoted in Tables 4-6 and 4-7 beyond the first 10 days are based on additional equipment and facility upgrades. These changes are assumed to be put into effect only if an order-of-magnitude estimate for the anticipated repair time exceeds certain values; i.e., only when the repair is of a magnitude that will make it worthwhile to increase capacity. Within each phase of expansion, production capacity is expected to vary on a continuous basis. This variation is represented by a triangular distribution that has an expected, a low, and a high value, as shown in Tables 4-6 and 4-7.

Table 4-6 Production Rates by Time (SRRQ and Others, Marine-Based)

Days	Production Rate			Remarks
	Low	Expected	High	
0 to ½ day	0-tpd	0-tpd	0-tpd	Time required for contractor to commence work
½ to ~3 days	2,000-tpd	4,000-tpd	8,000-tpd	
~3 to 10 days	4,000-tpd	10,000-tpd	12,000-tpd	Maximum SRRQ capacity with current equipment and configuration.
10 to 90 days	8,000-tpd	20,000-tpd	24,000-tpd	Addition of more mining equipment. Increase only if repairs are estimated to exceed 180 days duration.
90 to 180 days	20,000-tpd	40,000-tpd	48,000-tpd	Additional barge loading facility. Increase only if repairs are estimated to exceed 360 days duration.
180+ days	30,000-tpd	50,000-tpd	58,000-tpd	SRRQ plus other marine sources. Increase only if repairs are estimated to exceed 720 days duration.

tpd = tons per day

Table 4-7 Production Rates by Time (Local Quarries, Land-Based)

Days	Production Rate Low	Production Rate Expected	Production Rate High	Remarks
0 to ½ day	0-tpd	0-tpd	0-tpd	Time required for contractor to commence work
½ to ~3 days	1,300-tpd	1,800-tpd	6,200-tpd	
~3 to 10 days	2,700-tpd	4,400-tpd	9,300-tpd	Maximum combined capacity (local quarries) with current equipment and configuration.
10 to 90 days	5,300-tpd	8,800-tpd	18,000-tpd	Additional mining equipment. Increase only if repairs are estimated to exceed 180 days duration.
90 to 180 days	13,000-tpd	18,000-tpd	37,000-tpd	Configuration modifications. Increase only if repairs are estimated to exceed 360 days duration.
180+ days	20,000-tpd	22,000-tpd	45,000-tpd	Further configuration modifications & additional mining equipment. Increase only if repairs are estimated to exceed 720 days duration.

tpd = tons per day

Table 4-8 Production Rates by Activity (Placing Rates)

Activity	Production Rate	Remarks
Levee Repair	3,200-tpd	rate of 1 placing rig; max 1 placing rig per 2,000-ft
Interior Levee Protection Marine Access	3,200-tpd	rate of 1 placing rig; max 1 placing rig per week's worth of activity
Land Access (trucking)	5,280-tpd	1 truck (22-tons) every 5 minutes (50- min-hr)
End Capping	1,600-tpd	per breach
Levee Closure	4,800-tpd	rate of 1 placing rig; max 1 placing rig per 300-ft

tpd = tons per day

4.10 Ongoing Flood Fighting Activities

Seasonal flood fighting activities on non-flooded islands are assumed to be ongoing during emergency operations, thus detracting resources and reducing response capacity during a limited time of the year.

The model allows for separate percent reductions in material supply sourced from the SRRQ and the local quarries that is available for the event-related emergency response. The percent reduction can be input by the user and is based on the nominal daily production rate, which is 4,000 tons per day for the SRRQ and 1,800 tons per day for the local quarries. The default value is arbitrarily set to 25% for both SRRQ and local quarries. Input from DWR is required to finalize these values, such that realistic levels of resources are detracted to cover the flood fighting activities. The model assumes that flood fighting activities occur during the months of December through March.

4.11 Dewatering

Dewatering operations will commence at the time of island closure or completion of all repairs on a flooded island (depending on the user input for the sequence—see Section 4.6). It is assumed that installation of pumps is commenced several days ahead of the anticipated closure of the island; thus, no lag time is assumed between island closure (or completion of repairs) and start of pumping. The pump rate is based on the assumption that only 42" pumps will be utilized and that these pumps operate at an efficiency of 80%, resulting in 107 cubic feet per second per pump. One pump will be allocated for every 20,000 acre-ft to be dewatered. The number of pumps is thus related to the volume of water to be pumped. The total pump rate is reduced by 50 cubic feet per second to account for seepage effects. These assumptions are based on a review of the Jones Tract data.

4.12 Cost

Cost is computed based on $55/ton of material placed and $35/acre-ft of water pumped. The two unit rates given include the cost of labor, equipment, and material.

5. Sample Input and Output

This section presents sample input and output for two sequences. The first sequence includes a number of breaches and damaged sections on 7 islands. The second sequence includes a single breach on each of 10 islands, all islands having equal priority.

5.1 Sequence 1

The first sample sequence (sequence # 8001) involves 7 islands that are impacted. A number of the islands have multiple breaches and/or damaged sections. The islands belong to three island priority groups. Island 10 is further expected to experience a secondary breach on its segment 2 on day 120, if the damaged section on that segment is not repaired by then. Tables 5-1 through 5-3 present the input (damage, assignment to island priority groups, and repair work order prioritization for each island priority group). Table 5-4 presents the internal Damage Summary array, which keeps track of the repairs and their priorities. The main output from the ER&R model is presented in Table 5-5—it gives summaries for the sequence and for each island (completion time for repairs and dewatering, quantity of rock placed, dewatering pump rate, number of pumps used simultaneously, and total cost). The output that is passed on to the Water Quality model is presented in Table 5-6—it presents a summary line for each flooded island as well as for each segment on that island (completion time for all repairs, for breach repairs only and for dewatering, and dewatering pump rate).

Table 5-1 Sequence 1 Damage Input

Sequence Id	Day Of Year				
8001	200				
Island Id	**Segment**	**Damage State**	**Length (Feet)**	**Slump Height /Breach Growth Rate (Inches)**	**Time (Days)**
3	8	2	300	4	1
10	2	1	500	36	1
2	3	2	175	4	1
8	1	1	675	30	1
8	1	1	350	30	1
7	6	1	800	42	1
20	4	2	150	4	1
20	5	2	225	4	1
5	5	2	250	4	1
10	1	1	425	30	1
20	6	1	600	24	1
8	2	1	100	30	1
10	2	2	100	4	120

Table 5-2 Sequence 1 Island Priority Group Input

Sequence Id	
8001	
Island Id	**Island Priority Group**
3	1
2	3
5	2
7	2
8	1
10	1
20	2

Table 5-3 Sequence 1 Repair Order Prioritization Input

Sequence Id						
8001						
Island Priority Group	**RT1**	**RT2**	**RT3**	**RT4**	**RT5**	**RT6**
1	1	2	2	2	3	1
2	1	0	4	0	5	1
3	1	0	7	6	6	1

Table 5-4 Damage Summary (Internal Array) for Sequence 1

0 island	1 segment	2 priority	3 # damage	4 Ld	5 #breach	6 Lb	7 Lexp	8 status	9 flooded	10 w # DB_Ma	11 RT1	12 RT2	13 RT3	14 RT4	15 RT5	16 pRT1	17 pRT2	18 pRT3	19 pRT4	20 pRT5	21 cw(MHHW)	22 Tbreach	23 damstat	24 damTst	25 damTend	26 damVol	27 brstat	28 brTst	29 brTend	30 brVol	31 erosstat	32 erosTst	33 erosTend	34 erosVol	35 Tbeg	36 Tend	37 dew Tbeg	38 dew Tend	39 TotVol	40 TotCost	41 PumpRate
8001	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00	1,093,111	0	0.00	0.00	166,660	0	0.00	0.00	167,764	0.00	127.66	0.00	372.87	1,427,535	142,753,505	6
3	0	1	0	0	1	300	40443	1	1	19	0	0	0	0	0	0	0	0	0	0	0	1	100	0.00	0.00	0	100	46.15	98.41	56,576	100	1.50	52.88	167,764	1.50	98.41	98.41	154.17	224,340	22,433,956	56.46816
3	1	1	0	0	0	0	4604	1	1	20	0	1	0	0	0	0	2001012	0	0	0	31	0	0	0.00	0.00	0	0	0.00	0.00	0	101	1.50	2.45	19,098	1.50	2.45	0.00	0.00	19,098	1,909,807	0
3	2	1	0	0	0	0	4934	1	1	21	0	1	0	0	0	0	2001012	0	0	0	31	0	0	0.00	0.00	0	0	0.00	0.00	0	101	45.45	46.47	20,467	45.45	46.47	0.00	0.00	20,467	2,046,696	0
3	3	1	0	0	0	0	5200	1	1	22	0	1	0	0	0	0	2001012	0	0	0	31	0	0	0.00	0.00	0	0	0.00	0.00	0	101	46.47	47.55	21,570	46.47	47.55	0.00	0.00	21,570	2,157,037	0
3	4	1	0	0	0	0	5877	1	1	23	0	1	0	0	0	0	2001012	0	0	0	31	0	0	0.00	0.00	0	0	0.00	0.00	0	101	47.55	48.77	24,379	47.55	48.77	0.00	0.00	24,379	2,437,867	0
3	5	1	0	0	0	0	5196	1	1	24	0	1	0	0	0	0	2001012	0	0	0	31	0	0	0.00	0.00	0	0	0.00	0.00	0	101	48.77	49.85	21,554	48.77	49.85	0.00	0.00	21,554	2,155,378	0
3	6	1	0	0	0	0	5895	1	1	25	0	1	0	0	0	0	2001012	0	0	0	31	0	0	0.00	0.00	0	0	0.00	0.00	0	101	49.85	51.07	24,453	49.85	51.07	0.00	0.00	24,453	2,445,333	0
3	7	1	0	0	0	0	4675	1	1	26	0	1	0	0	0	0	2001012	0	0	0	31	0	0	0.00	0.00	0	0	0.00	0.00	0	101	51.07	52.04	19,393	51.07	52.04	0.00	0.00	19,393	1,939,259	0
3	8	1	0	0	1	300	4062	1	1	27	0	1	0	1	1	0	2001012	0	2001014	3001015	31	1	0	0.00	0.00	0	102	46.15	98.41	56,576	101	52.04	52.88	16,850	46.15	98.41	0.00	0.00	73,426	7,342,578	0
2	0	3	0	0	1	175	42782	1	1	10	0	0	0	0	0	0	0	0	0	0	0	1	100	0.00	0.00	0	100	115.17	130.42	31,260	100	0.00	0.00	0	115.17	130.42	130.42	263.93	31,260	3,125,985	56.46816
2	1	3	0	0	0	0	5115	0	1	11	0	1	0	0	0	0	0	0	0	0	28	0	0	0.00	0.00	0	0	0.00	0.00	0	0	0.00	0.00	0	0.00	0.00	0.00	0.00	0	0	0
2	2	3	0	0	0	0	5793	0	1	12	0	1	0	0	0	0	0	0	0	0	28	0	0	0.00	0.00	0	0	0.00	0.00	0	0	0.00	0.00	0	0.00	0.00	0.00	0.00	0	0	0
2	3	3	0	0	1	175	4453	1	1	13	0	1	0	1	1	0	0	0	6003074	6003075	28	1	0	0.00	0.00	0	102	115.17	130.42	31,260	0	0.00	0.00	0	115.17	130.42	0.00	0.00	31,260	3,125,985	0
2	4	3	0	0	0	0	5963	0	1	14	0	1	0	0	0	0	0	0	0	0	28	0	0	0.00	0.00	0	0	0.00	0.00	0	0	0.00	0.00	0	0.00	0.00	0.00	0.00	0	0	0
2	5	3	0	0	0	0	5800	0	1	15	0	1	0	0	0	0	0	0	0	0	28	0	0	0.00	0.00	0	0	0.00	0.00	0	0	0.00	0.00	0	0.00	0.00	0.00	0.00	0	0	0
2	6	3	0	0	0	0	5352	0	1	16	0	1	0	0	0	0	0	0	0	0	28	0	0	0.00	0.00	0	0	0.00	0.00	0	0	0.00	0.00	0	0.00	0.00	0.00	0.00	0	0	0
2	7	3	0	0	0	0	4337	0	1	17	0	1	0	0	0	0	0	0	0	0	28	0	0	0.00	0.00	0	0	0.00	0.00	0	0	0.00	0.00	0	0.00	0.00	0.00	0.00	0	0	0
2	8	3	0	0	0	0	5969	0	1	18	0	1	0	0	0	0	0	0	0	0	28	0	0	0.00	0.00	0	0	0.00	0.00	0	0	0.00	0.00	0	0.00	0.00	0.00	0.00	0	0	0
5	0	2	0	0	1	250	38252	1	1	37	0	0	0	0	0	0	0	0	0	0	0	1	100	0.00	0.00	0	100	98.61	109.79	31,305	100	0.00	0.00	0	98.61	109.79	109.79	208.64	31,305	3,130,453	163.3543
5	1	2	0	0	0	0	4187	0	1	38	0	1	0	0	0	0	0	0	0	0	12	0	0	0.00	0.00	0	0	0.00	0.00	0	0	0.00	0.00	0	0.00	0.00	0.00	0.00	0	0	0
5	2	2	0	0	0	0	5494	0	1	39	0	1	0	0	0	0	0	0	0	0	12	0	0	0.00	0.00	0	0	0.00	0.00	0	0	0.00	0.00	0	0.00	0.00	0.00	0.00	0	0	0
5	3	2	0	0	0	0	4263	0	1	40	0	1	0	0	0	0	0	0	0	0	12	0	0	0.00	0.00	0	0	0.00	0.00	0	0	0.00	0.00	0	0.00	0.00	0.00	0.00	0	0	0
5	4	2	0	0	0	0	5315	0	1	41	0	1	0	0	0	0	0	0	0	0	12	0	0	0.00	0.00	0	0	0.00	0.00	0	0	0.00	0.00	0	0.00	0.00	0.00	0.00	0	0	0
5	5	2	0	0	1	250	4332	1	1	42	0	1	0	1	1	0	0	0	0	5002045	12	1	0	0.00	0.00	0	101	98.61	109.79	31,305	0	0.00	0.00	0	98.61	109.79	0.00	0.00	31,305	3,130,453	0
5	6	2	0	0	0	0	4435	0	1	43	0	1	0	0	0	0	0	0	0	0	12	0	0	0.00	0.00	0	0	0.00	0.00	0	0	0.00	0.00	0	0.00	0.00	0.00	0.00	0	0	0
5	7	2	0	0	0	0	5981	0	1	44	0	1	0	0	0	0	0	0	0	0	12	0	0	0.00	0.00	0	0	0.00	0.00	0	0	0.00	0.00	0	0.00	0.00	0.00	0.00	0	0	0
5	8	2	0	0	0	0	4245	0	1	45	0	1	0	0	0	0	0	0	0	0	12	0	0	0.00	0.00	0	0	0.00	0.00	0	0	0.00	0.00	0	0.00	0.00	0.00	0.00	0	0	0
7	0	2	1	800	0	0	38719	1	0	55	0	0	0	0	0	0	0	0	0	0	0	0	100	1.40	92.17	316,587	100	0.00	0.00	0	100	0.00	0.00	0	1.40	92.17	0.00	0.00	316,587	31,658,667	0
7	1	2	0	0	0	0	5210	0	0	56	0	0	0	0	0	0	0	0	0	0	32	0	0	0.00	0.00	0	0	0.00	0.00	0	0	0.00	0.00	0	0.00	0.00	0.00	0.00	0	0	0
7	2	2	0	0	0	0	4696	0	0	57	0	0	0	0	0	0	0	0	0	0	32	0	0	0.00	0.00	0	0	0.00	0.00	0	0	0.00	0.00	0	0.00	0.00	0.00	0.00	0	0	0
7	3	2	0	0	0	0	4752	0	0	58	0	0	0	0	0	0	0	0	0	0	32	0	0	0.00	0.00	0	0	0.00	0.00	0	0	0.00	0.00	0	0.00	0.00	0.00	0.00	0	0	0
7	4	2	0	0	0	0	4045	0	0	59	0	0	0	0	0	0	0	0	0	0	32	0	0	0.00	0.00	0	0	0.00	0.00	0	0	0.00	0.00	0	0.00	0.00	0.00	0.00	0	0	0
7	5	2	0	0	0	0	5544	0	0	60	0	0	0	0	0	0	0	0	0	0	32	0	0	0.00	0.00	0	0	0.00	0.00	0	0	0.00	0.00	0	0.00	0.00	0.00	0.00	0	0	0
7	6	2	1	800	0	0	4299	1	0	61	1	0	0	0	0	1002051	0	0	0	0	32	0	101	1.40	92.17	316,587	0	0.00	0.00	0	0	0.00	0.00	0	1.40	92.17	0.00	0.00	316,587	31,658,667	0
7	7	2	0	0	0	0	4192	0	0	62	0	0	0	0	0	0	0	0	0	0	32	0	0	0.00	0.00	0	0	0.00	0.00	0	0	0.00	0.00	0	0.00	0.00	0.00	0.00	0	0	0
7	8	2	0	0	0	0	5981	0	0	63	0	0	0	0	0	0	0	0	0	0	32	0	0	0.00	0.00	0	0	0.00	0.00	0	0	0.00	0.00	0	0.00	0.00	0.00	0.00	0	0	0
8	0	1	3	1125	0	0	37344	1	0	64	0	0	0	0	0	0	0	0	0	0	0	0	100	1.10	47.09	354,000	100	0.00	0.00	0	100	0.00	0.00	0	1.10	47.09	0.00	0.00	354,000	35,400,000	0
8	1	1	2	1025	0	0	3811	1	0	65	1	0	0	0	0	1001031	0	0	0	0	34	0	102	1.10	47.09	322,533	0	0.00	0.00	0	0	0.00	0.00	0	1.10	47.09	0.00	0.00	322,533	32,253,333	0
8	2	1	1	100	0	0	4773	1	0	66	1	0	0	0	0	1001031	0	0	0	0	34	0	101	1.30	14.41	31,467	0	0.00	0.00	0	0	0.00	0.00	0	1.30	14.41	0.00	0.00	31,467	3,146,667	0
8	3	1	0	0	0	0	4397	0	0	67	0	0	0	0	0	0	0	0	0	0	34	0	0	0.00	0.00	0	0	0.00	0.00	0	0	0.00	0.00	0	0.00	0.00	0.00	0.00	0	0	0
8	4	1	0	0	0	0	4880	0	0	68	0	0	0	0	0	0	0	0	0	0	34	0	0	0.00	0.00	0	0	0.00	0.00	0	0	0.00	0.00	0	0.00	0.00	0.00	0.00	0	0	0
8	5	1	0	0	0	0	5642	0	0	69	0	0	0	0	0	0	0	0	0	0	34	0	0	0.00	0.00	0	0	0.00	0.00	0	0	0.00	0.00	0	0.00	0.00	0.00	0.00	0	0	0
8	6	1	0	0	0	0	5659	0	0	70	0	0	0	0	0	0	0	0	0	0	34	0	0	0.00	0.00	0	0	0.00	0.00	0	0	0.00	0.00	0	0.00	0.00	0.00	0.00	0	0	0
8	7	1	0	0	0	0	4072	0	0	71	0	0	0	0	0	0	0	0	0	0	34	0	0	0.00	0.00	0	0	0.00	0.00	0	0	0.00	0.00	0	0.00	0.00	0.00	0.00	0	0	0
8	8	1	0	0	0	0	4110	0	0	72	0	0	0	0	0	0	0	0	0	0	34	0	0	0.00	0.00	0	0	0.00	0.00	0	0	0.00	0.00	0	0.00	0.00	0.00	0.00	0	0	0
10	0	1	2	925	1	100	37627	1	0	82	0	0	0	0	0	0	0	0	0	0	0	120	100	46.25	114.97	282,578	100	0.00	0.00	0	100	0.00	0.00	0	46.25	114.97	0.00	0.00	282,578	28,257,778	0
10	1	1	1	425	0	0	3778	1	0	83	0	1	1	0	0	0	2001022	2001023	0	0	21	0	101	46.25	95.99	119,378	0	0.00	0.00	0	101	0.00	0.00	0	46.25	95.99	0.00	0.00	119,378	11,937,778	0
10	2	1	1	500	1	100	4797	1	0	84	0	1	1	1	1	0	2001022	2001023	2001024	3001025	21	120	101	46.35	114.97	163,200	102	0.00	0.00	0	101	0.00	0.00	0	46.35	114.97	0.00	0.00	163,200	16,320,000	0
10	3	1	0	0	0	0	4683	1	0	85	0	1	0	0	0	0	2001022	0	0	0	21	0	0	0.00	0.00	0	0	0.00	0.00	0	101	0.00	0.00	0	0.00	0.00	0.00	0.00	0	0	0
10	4	1	0	0	0	0	4413	1	0	86	0	1	0	0	0	0	2001022	0	0	0	21	0	0	0.00	0.00	0	0	0.00	0.00	0	101	0.00	0.00	0	0.00	0.00	0.00	0.00	0	0	0
10	5	1	0	0	0	0	4773	1	0	87	0	1	0	0	0	0	2001022	0	0	0	21	0	0	0.00	0.00	0	0	0.00	0.00	0	101	0.00	0.00	0	0.00	0.00	0.00	0.00	0	0	0
10	6	1	0	0	0	0	5498	1	0	88	0	1	0	0	0	0	2001022	0	0	0	21	0	0	0.00	0.00	0	0	0.00	0.00	0	101	0.00	0.00	0	0.00	0.00	0.00	0.00	0	0	0
10	7	1	0	0	0	0	4515	1	0	89	0	1	0	0	0	0	2001022	0	0	0	21	0	0	0.00	0.00	0	0	0.00	0.00	0	101	0.00	0.00	0	0.00	0.00	0.00	0.00	0	0	0
10	8	1	0	0	0	0	5170	1	0	90	0	1	0	0	0	0	2001022	0	0	0	21	0	0	0.00	0.00	0	0	0.00	0.00	0	101	0.00	0.00	0	0.00	0.00	0.00	0.00	0	0	0
20	0	2	1	600	2	375	40077	1	1	172	0	0	0	0	0	0	0	0	0	0	0	1	100	98.51	127.66	139,947	100	109.79	124.66	47,520	100	0.00	0.00	0	98.51	127.66	127.66	372.87	187,467	18,746,667	56.46816
20	1	2	0	0	0	0	5999	0	1	173	0	1	0	0	0	0	0	0	0	0	16	0	0	0.00	0.00	0	0	0.00	0.00	0	0	0.00	0.00	0	0.00	0.00	0.00	0.00	0	0	0
20	2	2	0	0	0	0	4337	0	1	174	0	1	0	0	0	0	0	0	0	0	16	0	0	0.00	0.00	0	0	0.00	0.00	0	0	0.00	0.00	0	0.00	0.00	0.00	0.00	0	0	0
20	3	2	0	0	0	0	4317	0	1	175	0	1	0	0	0	0	0	0	0	0	16	0	0	0.00	0.00	0	0	0.00	0.00	0	0	0.00	0.00	0	0.00	0.00	0.00	0.00	0	0	0
20	4	2	0	0	1	150	5733	1	1	176	0	1	0	1	1	0	0	0	0	5002065	16	1	0	0.00	0.00	0	101	109.79	116.11	16,427	0	0.00	0.00	0	109.79	116.11	0.00	0.00	16,427	1,642,667	0
20	5	2	0	0	1	225	4156	1	1	177	0	1	0	1	1	0	0	0	0	5002065	16	1	0	0.00	0.00	0	101	116.11	124.66	31,093	0	0.00	0.00	0	116.11	124.66	0.00	0.00	31,093	3,109,333	0
20	6	2	1	600	0	0	4926	1	1	178	0	1	1	0	0	0	0	4002063	0	0	16	0	101	98.51	127.66	139,947	0	0.00	0.00	0	0	0.00	0.00	0	98.51	127.66	0.00	0.00	139,947	13,994,667	0
20	7	2	0	0	0	0	5950	0	1	179	0	1	0	0	0	0	0	0	0	0	16	0	0	0.00	0.00	0	0	0.00	0.00	0	0	0.00	0.00	0	0.00	0.00	0.00	0.00	0	0	0
20	8	2	0	0	0	0	4659	0	1	180	0	1	0	0	0	0	0	0	0	0	16	0	0	0.00	0.00	0	0	0.00	0.00	0	0	0.00	0.00	0	0.00	0.00	0.00	0.00	0	0	0

Table 5-5 Sequence 1 Output

Sequence									Tend		Tend Dewater	Total Quantity	Total Cost	# of Pumps
8001									127.66		372.87	1,427,535	142,753,505	6
Island	**Segment**	**Priority**	**# of Dam**	**Ld**	**# of Breaches**	**Lb**	**Flooded**	**Tstart**	**Tend**	**Tstart Dewater**	**Tend Dewater**	**Total Quantity**	**Total Cost**	**Pump Rate**
3	0	1	0	0	1	300	1	1.50	98.41	98.41	154.17	224,340	22,433,956	56.47
2	0	3	0	0	1	175	1	115.17	130.42	130.42	263.93	31,260	3,125,985	56.47
5	0	2	0	0	1	250	1	98.61	109.79	109.79	208.64	31,305	3,130,453	163.35
7	0	2	1	800	0	0	0	1.40	92.17	0.00	0.00	316,587	31,658,667	0.00
8	0	1	3	1125	0	0	0	1.10	47.09	0.00	0.00	354,000	35,400,000	0.00
10	0	1	2	925	1	100	0	46.25	114.97	0.00	0.00	282,578	28,257,778	0.00
20	0	2	1	600	2	375	1	98.51	127.66	127.66	372.87	187,467	18,746,667	56.47

Table 5-6 Output to Water Quality Model for Sequence 1

Sequence
8001

Island	Segment	# Of Breaches	Lb	Tbreach	Tstart Breach Repair	Tend Breach Repair	Tstart All Repairs	Tend All Repairs	Tstart Dewater	Tend Dewater	Pump Rate
3	0	1	300	1	46.15	98.41	1.50	98.41	98.41	154.17	56.47
3	1	0	0	0	0.00	0.00	1.50	2.45	0.00	0.00	0.00
3	2	0	0	0	0.00	0.00	45.45	46.47	0.00	0.00	0.00
3	3	0	0	0	0.00	0.00	46.47	47.55	0.00	0.00	0.00
3	4	0	0	0	0.00	0.00	47.55	48.77	0.00	0.00	0.00
3	5	0	0	0	0.00	0.00	48.77	49.85	0.00	0.00	0.00
3	6	0	0	0	0.00	0.00	49.85	51.07	0.00	0.00	0.00
3	7	0	0	0	0.00	0.00	51.07	52.04	0.00	0.00	0.00
3	8	1	300	1	46.15	98.41	46.15	98.41	0.00	0.00	0.00
2	0	1	175	1	115.17	130.42	115.17	130.42	130.42	263.93	56.47
2	1	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	2	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	3	1	175	1	115.17	130.42	115.17	130.42	0.00	0.00	0.00
2	4	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	5	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	6	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	7	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	8	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	0	1	250	1	98.61	109.79	98.61	109.79	109.79	208.64	163.35
5	1	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	2	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	3	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	4	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	5	1	250	1	98.61	109.79	98.61	109.79	0.00	0.00	0.00
5	6	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	7	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	8	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	0	2	375	1	109.79	124.66	98.51	127.66	127.66	372.87	56.47
20	1	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	2	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	3	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	4	1	150	1	109.79	116.11	109.79	116.11	0.00	0.00	0.00
20	5	1	225	1	116.11	124.66	116.11	124.66	0.00	0.00	0.00
20	6	0	0	0	0.00	0.00	98.51	127.66	0.00	0.00	0.00
20	7	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	8	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00

5.2 Sequence 2

The second sample sequence (sequence # 8002) involves 10 islands that are impacted. Each island has experienced a single breach that occurs on Day 1. The islands belong to the same island priority group. Tables 5-7 through 5-9 present the input (damage, assignment to island priority groups, and repair work order prioritization for each island priority group). Table 5-10 presents the internal Damage Summary array, which keeps track of the repairs and their priorities. The main output from the ER&R model is presented in Table 5-11 and the output that is passed on to the Water Quality model is presented in Table 5-12.

Table 5-7 Sequence 2 Damage Input

Sequence Id	Day Of Year
8002	180

Island Id	Segment	Damage State	Length (Feet)	Slump Height /Breach Growth Rate (Inches)	Time (Days)
1	8	2	300	4	1
25	4	2	250	4	1
9	5	2	175	4	1
3	2	2	375	4	1
30	2	2	350	4	1
8	1	2	200	4	1
44	6	2	300	4	1
43	5	2	425	4	1
10	7	2	375	4	1
11	2	2	275	4	1

Table 5-8 Sequence 2 Island Priority Group Input

Sequence Id
8002

Island Id	Island Priority Group
1	1
25	1
9	1
3	1
30	1
8	1
44	1
43	1
10	1
11	1

Table 5-9 Sequence 2 Repair Order Prioritization Input

Sequence Id						
8002						
Island Priority Group	**RT1**	**RT2**	**RT3**	**RT4**	**RT5**	**RT6**
1	1	2	2	2	3	1
2	1	0	4	0	5	1
3	1	0	7	6	6	1

Table 5-10 Damage Summary (Internal Array) for Sequence 2

0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41
island	segment	priority	# damage	Ld	#breach	Lb	Lexp	status	flooded	w # DB_Ma	RT1	RT2	RT3	RT4	RT5	pRT1	pRT2	pRT3	pRT4	pRT5	cw(MHHW)	Tbreach	damstat	damTst	damTend	damVol	brstat	brTst	brTend	brVol	erosstat	erosTst	erosTend	erosVol	Tbeg	Tend	dew Tbeg	dew Tend	TotVol	TotCost	PumpRate
8002	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00	0	0	0.00	0.00	552,179	0	0.00	0.00	1,643,849	0.00	58.80	0.00	257.35	2,196,028	#########	57
1	0	1	0	0	1	300	41004	1	1	1	0	0	0	0	0	0	0	0	0	0	0	1	100	0.00	0.00	0	100	9.39	41.92	55,645	100	34.44	42.94	170,091	9.39	42.94	42.94	137.54	225,736	22,573,600	377.1266
1	1	1	0	0	0	0	4998	1	1	2	0	1	0	0	0	0	2001052	0	0	0	24	0	0	0.00	0.00	0	0	0.00	0.00	0	101	34.44	35.47	20,732	34.44	35.47	0.00	0.00	20,732	2,073,244	0
1	2	1	0	0	0	0	5044	1	1	3	0	1	0	0	0	0	2001052	0	0	0	24	0	0	0.00	0.00	0	0	0.00	0.00	0	101	35.47	36.52	20,923	35.47	36.52	0.00	0.00	20,923	2,092,326	0
1	3	1	0	0	0	0	5298	1	1	4	0	1	0	0	0	0	2001052	0	0	0	24	0	0	0.00	0.00	0	0	0.00	0.00	0	101	36.52	37.62	21,977	36.52	37.62	0.00	0.00	21,977	2,197,689	0
1	4	1	0	0	0	0	5520	1	1	5	0	1	0	0	0	0	2001052	0	0	0	24	0	0	0.00	0.00	0	0	0.00	0.00	0	101	37.62	38.76	22,898	37.62	38.76	0.00	0.00	22,898	2,289,778	0
1	5	1	0	0	0	0	4750	1	1	6	0	1	0	0	0	0	2001052	0	0	0	24	0	0	0.00	0.00	0	0	0.00	0.00	0	101	38.76	39.75	19,704	38.76	39.75	0.00	0.00	19,704	1,970,370	0
1	6	1	0	0	0	0	5717	1	1	7	0	1	0	0	0	0	2001052	0	0	0	24	0	0	0.00	0.00	0	0	0.00	0.00	0	101	39.75	40.94	23,715	39.75	40.94	0.00	0.00	23,715	2,371,496	0
1	7	1	0	0	0	0	4219	1	1	8	0	1	0	0	0	0	2001052	0	0	0	24	0	0	0.00	0.00	0	0	0.00	0.00	0	101	40.94	41.81	17,501	40.94	41.81	0.00	0.00	17,501	1,750,104	0
1	8	1	0	0	1	300	5458	1	1	9	0	1	0	1	1	0	2001052	0	2001054	3001055	24	1	0	0.00	0.00	0	102	9.39	41.92	55,645	101	41.81	42.94	22,641	9.39	42.94	0.00	0.00	78,286	7,828,593	0
25	0	1	0	0	1	250	41906	1	1	217	0	0	0	0	0	0	0	0	0	0	0	1	100	0.00	0.00	0	100	6.21	31.57	39,328	100	17.84	26.53	173,832	6.21	31.57	31.57	147.02	213,160	21,316,047	377.1266
25	1	1	0	0	0	0	4890	1	1	218	0	1	0	0	0	0	2001032	0	0	0	10	0	0	0.00	0.00	0	0	0.00	0.00	0	101	17.84	18.85	20,284	17.84	18.85	0.00	0.00	20,284	2,028,444	0
25	2	1	0	0	0	0	5507	1	1	219	0	1	0	0	0	0	2001032	0	0	0	10	0	0	0.00	0.00	0	0	0.00	0.00	0	101	18.85	19.99	22,844	18.85	19.99	0.00	0.00	22,844	2,284,385	0
25	3	1	0	0	0	0	4771	1	1	220	0	1	0	0	0	0	2001032	0	0	0	10	0	0	0.00	0.00	0	0	0.00	0.00	0	101	19.99	20.98	19,791	19.99	20.98	0.00	0.00	19,791	1,979,081	0
25	4	1	0	0	1	250	4885	1	1	221	0	1	0	1	1	0	2001032	0	2001034	3001035	10	1	0	0.00	0.00	0	102	6.21	31.57	39,328	101	20.98	22.00	20,264	6.21	31.57	0.00	0.00	59,592	5,959,188	0
25	5	1	0	0	0	0	4959	1	1	222	0	1	0	0	0	0	2001032	0	0	0	10	0	0	0.00	0.00	0	0	0.00	0.00	0	101	22.00	23.03	20,571	22.00	23.03	0.00	0.00	20,571	2,057,067	0
25	6	1	0	0	0	0	5355	1	1	223	0	1	0	0	0	0	2001032	0	0	0	10	0	0	0.00	0.00	0	0	0.00	0.00	0	101	23.03	24.14	22,213	23.03	24.14	0.00	0.00	22,213	2,221,333	0
25	7	1	0	0	0	0	5959	1	1	224	0	1	0	0	0	0	2001032	0	0	0	10	0	0	0.00	0.00	0	0	0.00	0.00	0	101	24.14	25.37	24,719	24.14	25.37	0.00	0.00	24,719	2,471,881	0
25	8	1	0	0	0	0	5580	1	1	225	0	1	0	0	0	0	2001032	0	0	0	10	0	0	0.00	0.00	0	0	0.00	0.00	0	101	25.37	26.53	23,147	25.37	26.53	0.00	0.00	23,147	2,314,667	0
9	0	1	0	0	1	175	42433	1	1	73	0	0	0	0	0	0	0	0	0	0	0	1	100	0.00	0.00	0	100	1.90	15.87	31,659	100	1.10	9.90	176,018	1.10	15.87	15.87	164.80	207,677	20,767,704	56.46816
9	1	1	0	0	0	0	5494	1	1	74	0	1	0	0	0	0	2001012	0	0	0	38	0	0	0.00	0.00	0	0	0.00	0.00	0	101	1.10	2.24	22,790	1.10	2.24	0.00	0.00	22,790	2,278,993	0
9	2	1	0	0	0	0	5366	1	1	75	0	1	0	0	0	0	2001012	0	0	0	38	0	0	0.00	0.00	0	0	0.00	0.00	0	101	2.24	3.35	22,259	2.24	3.35	0.00	0.00	22,259	2,225,896	0
9	3	1	0	0	0	0	5781	1	1	76	0	1	0	0	0	0	2001012	0	0	0	38	0	0	0.00	0.00	0	0	0.00	0.00	0	101	3.35	4.55	23,980	3.35	4.55	0.00	0.00	23,980	2,398,044	0
9	4	1	0	0	0	0	4646	1	1	77	0	1	0	0	0	0	2001012	0	0	0	38	0	0	0.00	0.00	0	0	0.00	0.00	0	101	4.55	5.52	19,272	4.55	5.52	0.00	0.00	19,272	1,927,230	0
9	5	1	0	0	1	175	5061	1	1	78	0	1	0	1	1	0	2001012	0	2001014	3001015	38	1	0	0.00	0.00	0	102	1.90	15.87	31,659	101	5.52	6.56	20,994	1.90	15.87	0.00	0.00	52,652	5,265,244	0
9	6	1	0	0	0	0	5915	1	1	79	0	1	0	0	0	0	2001012	0	0	0	38	0	0	0.00	0.00	0	0	0.00	0.00	0	101	6.56	7.79	24,536	6.56	7.79	0.00	0.00	24,536	2,453,630	0
9	7	1	0	0	0	0	5125	1	1	80	0	1	0	0	0	0	2001012	0	0	0	38	0	0	0.00	0.00	0	0	0.00	0.00	0	101	7.79	8.85	21,259	7.79	8.85	0.00	0.00	21,259	2,125,926	0
9	8	1	0	0	0	0	5045	1	1	81	0	1	0	0	0	0	2001012	0	0	0	38	0	0	0.00	0.00	0	0	0.00	0.00	0	101	8.85	9.90	20,927	8.85	9.90	0.00	0.00	20,927	2,092,741	0
3	0	1	0	0	1	375	40368	1	1	19	0	0	0	0	0	0	0	0	0	0	0	1	100	0.00	0.00	0	100	15.13	62.68	72,292	100	58.80	67.17	167,452	15.13	67.17	67.17	122.94	239,744	23,974,400	56.46816
3	1	1	0	0	0	0	4604	1	1	20	0	1	0	0	0	0	2001082	0	0	0	31	0	0	0.00	0.00	0	0	0.00	0.00	0	101	58.80	59.75	19,098	58.80	59.75	0.00	0.00	19,098	1,909,807	0
3	2	1	0	0	1	375	4559	1	1	21	0	1	0	1	1	0	2001082	0	2001084	3001085	31	1	0	0.00	0.00	0	102	15.13	62.68	72,292	101	59.75	60.70	18,911	15.13	62.68	0.00	0.00	91,203	9,120,296	0
3	3	1	0	0	0	0	5200	1	1	22	0	1	0	0	0	0	2001082	0	0	0	31	0	0	0.00	0.00	0	0	0.00	0.00	0	101	60.70	61.78	21,570	60.70	61.78	0.00	0.00	21,570	2,157,037	0
3	4	1	0	0	0	0	5877	1	1	23	0	1	0	0	0	0	2001082	0	0	0	31	0	0	0.00	0.00	0	0	0.00	0.00	0	101	61.78	63.00	24,379	61.78	63.00	0.00	0.00	24,379	2,437,867	0
3	5	1	0	0	0	0	5196	1	1	24	0	1	0	0	0	0	2001082	0	0	0	31	0	0	0.00	0.00	0	0	0.00	0.00	0	101	63.00	64.07	21,554	63.00	64.07	0.00	0.00	21,554	2,155,378	0
3	6	1	0	0	0	0	5895	1	1	25	0	1	0	0	0	0	2001082	0	0	0	31	0	0	0.00	0.00	0	0	0.00	0.00	0	101	64.07	65.30	24,453	64.07	65.30	0.00	0.00	24,453	2,445,333	0
3	7	1	0	0	0	0	4675	1	1	26	0	1	0	0	0	0	2001082	0	0	0	31	0	0	0.00	0.00	0	0	0.00	0.00	0	101	65.30	66.27	19,393	65.30	66.27	0.00	0.00	19,393	1,939,259	0
3	8	1	0	0	0	0	4362	1	1	27	0	1	0	0	0	0	2001082	0	0	0	31	0	0	0.00	0.00	0	0	0.00	0.00	0	101	66.27	67.17	18,094	66.27	67.17	0.00	0.00	18,094	1,809,422	0
30	0	1	0	0	1	350	37976	1	1	262	0	0	0	0	0	0	0	0	0	0	0	1	100	0.00	0.00	0	100	13.55	54.64	54,613	100	50.92	58.80	157,530	13.55	58.80	58.80	257.35	212,143	21,214,287	56.46816
30	1	1	0	0	0	0	4686	1	1	263	0	1	0	0	0	0	2001072	0	0	0	18	0	0	0.00	0.00	0	0	0.00	0.00	0	101	50.92	51.89	19,438	50.92	51.89	0.00	0.00	19,438	1,943,822	0
30	2	1	0	0	1	350	3888	1	1	264	0	1	0	1	1	0	2001072	0	2001074	3001075	18	1	0	0.00	0.00	0	102	13.55	54.64	54,613	101	51.89	52.70	16,128	13.55	54.64	0.00	0.00	70,741	7,074,080	0
30	3	1	0	0	0	0	4679	1	1	265	0	1	0	0	0	0	2001072	0	0	0	18	0	0	0.00	0.00	0	0	0.00	0.00	0	101	52.70	53.67	19,409	52.70	53.67	0.00	0.00	19,409	1,940,919	0
30	4	1	0	0	0	0	5350	1	1	266	0	1	0	0	0	0	2001072	0	0	0	18	0	0	0.00	0.00	0	0	0.00	0.00	0	101	53.67	54.78	22,193	53.67	54.78	0.00	0.00	22,193	2,219,259	0
30	5	1	0	0	0	0	4776	1	1	267	0	1	0	0	0	0	2001072	0	0	0	18	0	0	0.00	0.00	0	0	0.00	0.00	0	101	54.78	55.77	19,812	54.78	55.77	0.00	0.00	19,812	1,981,156	0
30	6	1	0	0	0	0	4553	1	1	268	0	1	0	0	0	0	2001072	0	0	0	18	0	0	0.00	0.00	0	0	0.00	0.00	0	101	55.77	56.72	18,887	55.77	56.72	0.00	0.00	18,887	1,888,652	0
30	7	1	0	0	0	0	4827	1	1	269	0	1	0	0	0	0	2001072	0	0	0	18	0	0	0.00	0.00	0	0	0.00	0.00	0	101	56.72	57.72	20,023	56.72	57.72	0.00	0.00	20,023	2,002,311	0
30	8	1	0	0	0	0	5217	1	1	270	0	1	0	0	0	0	2001072	0	0	0	18	0	0	0.00	0.00	0	0	0.00	0.00	0	101	57.72	58.80	21,641	57.72	58.80	0.00	0.00	21,641	2,164,089	0
8	0	1	0	0	1	200	38269	1	1	64	0	0	0	0	0	0	0	0	0	0	0	1	100	0.00	0.00	0	100	4.04	23.38	38,705	100	9.90	17.84	158,745	4.04	23.38	23.38	236.07	197,450	19,745,007	56.46816
8	1	1	0	0	1	200	4636	1	1	65	0	1	0	1	1	0	2001022	0	2001024	3001025	34	1	0	0.00	0.00	0	102	4.04	23.38	38,705	101	9.90	10.86	19,231	4.04	23.38	0.00	0.00	57,935	5,793,541	0
8	2	1	0	0	0	0	4873	1	1	66	0	1	0	0	0	0	2001022	0	0	0	34	0	0	0.00	0.00	0	0	0.00	0.00	0	101	10.86	11.87	20,214	10.86	11.87	0.00	0.00	20,214	2,021,393	0
8	3	1	0	0	0	0	4397	1	1	67	0	1	0	0	0	0	2001022	0	0	0	34	0	0	0.00	0.00	0	0	0.00	0.00	0	101	11.87	12.79	18,239	11.87	12.79	0.00	0.00	18,239	1,823,941	0
8	4	1	0	0	0	0	4880	1	1	68	0	1	0	0	0	0	2001022	0	0	0	34	0	0	0.00	0.00	0	0	0.00	0.00	0	101	12.79	13.80	20,243	12.79	13.80	0.00	0.00	20,243	2,024,296	0
8	5	1	0	0	0	0	5642	1	1	69	0	1	0	0	0	0	2001022	0	0	0	34	0	0	0.00	0.00	0	0	0.00	0.00	0	101	13.80	14.97	23,404	13.80	14.97	0.00	0.00	23,404	2,340,385	0
8	6	1	0	0	0	0	5659	1	1	70	0	1	0	0	0	0	2001022	0	0	0	34	0	0	0.00	0.00	0	0	0.00	0.00	0	101	14.97	16.14	23,474	14.97	16.14	0.00	0.00	23,474	2,347,437	0
8	7	1	0	0	0	0	4072	1	1	71	0	1	0	0	0	0	2001022	0	0	0	34	0	0	0.00	0.00	0	0	0.00	0.00	0	101	16.14	16.99	16,891	16.14	16.99	0.00	0.00	16,891	1,689,126	0
8	8	1	0	0	0	0	4110	1	1	72	0	1	0	0	0	0	2001022	0	0	0	34	0	0	0.00	0.00	0	0	0.00	0.00	0	101	16.99	17.84	17,049	16.99	17.84	0.00	0.00	17,049	1,704,889	0
44	0	1	0	0	1	300	38471	1	1	388	0	0	0	0	0	0	0	0	0	0	0	1	100	0.00	0.00	0	100	11.29	48.60	62,488	100	42.94	50.92	159,583	11.29	50.92	50.92	149.58	222,071	22,207,111	590.899
44	1	1	0	0	0	0	5528	1	1	389	0	1	0	0	0	0	2001062	0	0	0	38	0	0	0.00	0.00	0	0	0.00	0.00	0	101	42.94	44.09	22,931	42.94	44.09	0.00	0.00	22,931	2,293,096	0
44	2	1	0	0	0	0	5255	1	1	390	0	1	0	0	0	0	2001062	0	0	0	38	0	0	0.00	0.00	0	0	0.00	0.00	0	101	44.09	45.18	21,799	44.09	45.18	0.00	0.00	21,799	2,179,852	0
44	3	1	0	0	0	0	4325	1	1	391	0	1	0	0	0	0	2001062	0	0	0	38	0	0	0.00	0.00	0	0	0.00	0.00	0	101	45.18	46.08	17,941	45.18	46.08	0.00	0.00	17,941	1,794,074	0
44	4	1	0	0	0	0	5123	1	1	392	0	1	0	0	0	0	2001062	0	0	0	38	0	0	0.00	0.00	0	0	0.00	0.00	0	101	46.08	47.14	21,251	46.08	47.14	0.00	0.00	21,251	2,125,096	0
44	5	1	0	0	0	0	4785	1	1	393	0	1	0	0	0	0	2001062	0	0	0	38	0	0	0.00	0.00	0	0	0.00	0.00	0	101	47.14	48.13	19,849	47.14	48.13	0.00	0.00	19,849	1,984,889	0
44	6	1	0	0	1	300	4730	1	1	394	0	1	0	1	1	0	2001062	0	2001064	3001065	38	1	0	0.00	0.00	0	102	11.29	48.60	62,488	101	48.13	49.11	19,621	11.29	49.11	0.00	0.00	82,108	8,210,844	0
44	7	1	0	0	0	0	4063	1	1	395	0	1	0	0	0	0	2001062	0	0	0	38	0	0	0.00	0.00	0	0	0.00	0.00	0	101	49.11	49.95	16,854	49.11	49.95	0.00	0.00	16,854	1,685,393	0
44	8	1	0	0	0	0	4662	1	1	396	0	1	0	0	0	0	2001062	0	0	0	38	0	0	0.00	0.00	0	0	0.00	0.00	0	101	49.95	50.92	19,339	49.95	50.92	0.00	0.00	19,339	1,933,867	0
43	0	1	0	0	1	425	39452	1	1	379	0	0	0	0	0	0	0	0	0	0	0	1	100	0.00	0.00	0	100	18.96	80.27	87,544	100	75.11	83.29	163,653	18.96	83.29	83.29	98.62	251,196	25,119,644	56
43	1	1	0	0	0	0	5313	1	1	380	0	1	0	0	0	0	2001102	0	0	0	34	0	0	0.00	0.00	0	0	0.00	0.00	0	101	75.11	76.21	22,039	75.11	76.21	0.00	0.00	22,039	2,203,911	0
43	2	1	0	0	0	0	4950	1	1	381	0	1	0	0	0	0	2001102	0	0	0	34	0	0	0.00	0.00	0	0	0.00	0.00	0	101	76.21	77.24	20,533	76.21	77.24	0.00	0.00	20,533	2,053,333	0
43	3	1	0	0	0	0	4099	1	1	382	0	1	0	0	0	0	2001102	0	0	0	34	0	0	0.00	0.00	0	0	0.00	0.00	0	101	77.24	78.09	17,003	77.24	78.09	0.00	0.00	17,003	1,700,326	0
43	4	1	0	0	0	0	5366	1	1	383	0	1	0	0	0	0	2001102	0	0	0	34	0	0	0.00	0.00	0	0	0.00	0.00	0	101	78.09	79.20	22,259	78.09	79.20	0.00	0.00	22,259	2,225,896	0
43	5	1	0	0	1	425	3718	1	1	384	0	1	0	1	1	0	2001102	0	2001104	3001105	34	1	0	0.00	0.00	0	102	18.96	80.27	87,544	101	79.20	79.97	15,423	18.96	80.27	0.00	0.00	102,967	10,296,652	0
43	6	1	0	0	0	0	4843	1	1	385	0	1	0	0	0	0	2001102	0	0	0	34	0	0	0.00	0.00	0	0	0.00	0.00	0	101	79.97	80.98	20,089	79.97	80.98	0.00	0.00	20,089	2,008,948	0
43	7	1	0	0	0	0	5445	1	1	386	0	1	0	0	0	0	2001102	0	0	0	34	0	0	0.00	0.00	0	0	0.00	0.00	0	101	80.98	82.11	22,587	80.98	82.11	0.00	0.00	22,587	2,258,667	0
43	8	1	0	0	0	0	5718	1	1	387	0	1	0	0	0	0	2001102	0	0	0	34	0	0	0.00	0.00	0	0	0.00	0.00	0	101	82.11	83.29	23,719	82.11	83.29	0.00	0.00	23,719	2,371,911	0
10	0	1	0	0	1	375	38277	1	1	82	0	0	0	0	0	0	0	0	0	0	0	1	100	0.00	0.00	0	100	17.12	70.38	69,015	100	67.17	75.11	158,779	17.12	75.11	75.11	84.13	227,794	22,779,413	56
10	1	1	0	0	0	0	4203	1	1	83	0	1	0	0	0	0	2001092	0	0	0	21	0	0	0.00	0.00	0	0	0.00	0.00	0	101	67.17	68.04	17,435	67.17	68.04	0.00	0.00	17,435	1,743,467	0
10	2	1	0	0	0	0	5397	1	1	84	0	1	0	0	0	0	2001092	0	0	0	21	0	0	0.00	0.00	0	0	0.00	0.00	0	101	68.04	69.16	22,388	68.04	69.16	0.00	0.00	22,388	2,238,756	0
10	3	1	0	0	0	0	4683	1	1	85	0	1	0	0	0	0	2001092	0	0	0	21	0	0	0.00	0.00	0	0	0.00	0.00	0	101	69.16	70.13	19,426	69.16	70.13	0.00	0.00	19,426	1,942,578	0
10	4	1	0	0	0	0	4413	1	1	86	0	1	0	0	0	0	2001092	0	0	0	21	0	0	0.00	0.00	0	0	0.00	0.00	0	101	70.13	71.05	18,306	70.13	71.05	0.00	0.00	18,306	1,830,578	0
10	5	1	0	0	0	0	4773	1	1	87	0	1	0	0	0	0	2001092	0	0	0	21	0	0	0.00	0.00	0	0	0.00	0.00	0	101	71.05	72.04	19,799	71.05	72.04	0.00	0.00	19,799	1,979,911	0
10	6	1	0	0	0	0	5498	1	1	88	0	1	0	0	0	0	2001092	0	0	0	21	0	0	0.00	0.00	0	0	0.00	0.00	0	101	72.04	73.18	22,807	72.04	73.18	0.00	0.00	22,807	2,280,652	0
10	7	1	0	0	1	375	4140	1	1	89	0	1	0	1	1	0	2001092	0	2001094	3001095	21	1	0	0.00	0.00	0	102	17.12	70.38	69,015	101	73.18	74.04	17,173	17.12	74.04	0.00	0.00	86,189	8,618,880	0
10	8	1	0	0	0	0	5170	1	1	90	0	1	0	0	0	0	2001092	0	0	0	21	0	0	0.00	0.00	0	0	0.00	0.00	0	101	74.04	75.11	21,446	74.04	75.11	0.00	0.00	21,446	2,144,593	0
11	0	1	0	0	1	275	38129	1	1	91	0	0	0	0	0	0	0	0	0	0	0	1	100	0.00	0.00	0	100	7.85	35.91	40,891	100	26.53	34.44	158,165	7.85	35.91	35.91	125.20	199,055	19,905,541	56
11	1	1	0	0	0	0	5611	1	1	92	0	1	0	0	0	0	2001042	0	0	0	10	0	0	0.00	0.00	0	0	0.00	0.00	0	101	26.53	27.69	23,275	26.53	27.69	0.00	0.00	23,275	2,327,526	0
11	2	1	0	0	1	275	4408	1	1	93	0	1	0	1	1	0	2001042	0	2001044	3001045	10	1	0	0.00	0.00	0	102	7.85	35.91	40,891	101	27.69	28.61	18,285	7.85	35.91	0.00	0.00	59,176	5,917,570	0
11	3	1	0	0	0	0	4334	1	1	94	0	1	0	0	0	0	2001042	0	0	0	10	0	0	0.00	0.00	0	0	0.00	0.00	0	101	28.61	29.51	17,978	28.61	29.51	0.00	0.00	17,978	1,797,807	0
11	4	1	0	0	0	0	4070	1	1	95	0	1	0	0	0	0	2001042	0	0	0	10	0	0	0.00	0.00	0	0	0.00	0.00	0	101	29.51	30.35	16,883	29.51	30.35	0.00	0.00	16,883	1,688,296	0
11	5	1	0	0	0	0	4776	1	1	96	0	1	0	0	0	0	2001042	0	0	0	10	0	0	0.00	0.00	0	0	0.00	0.00	0	101	30.35	31.34	19,812	30.35	31.34	0.00	0.00	19,812	1,981,156	0
11	6	1	0	0	0	0	4207	1	1	97	0	1	0	0	0	0	2001042	0	0	0	10	0	0	0.00	0.00	0	0	0.00	0.00	0	101	31.34	32.21	17,451	31.34	32.21	0.00	0.00	17,451	1,745,126	0
11	7	1	0	0	0	0	5380	1	1	98	0	1	0	0	0	0	2001042	0	0	0	10	0	0	0.00	0.00	0	0	0.00	0.00	0	101	32.21	33.33	22,317	32.21	33.33	0.00	0.00	22,317	2,231,704	0
11	8	1	0	0	0	0	5343	1	1	99	0	1	0	0	0	0	2001042	0	0	0	10	0	0	0.00	0.00	0	0	0.00	0.00	0	101	33.33	34.44	22,164	33.33	34.44	0.00	0.00	22,164	2,216,356	0

Table 5-11 Sequence 2 Output

Sequence									Tend		Tend Dewater	Total Quantity	Total Cost	# of Pumps
8002									58.80		257.35	2,196,028	219,602,756	57
Island	**Segment**	**Priority**	**# of Dam**	**Ld**	**# of Breaches**	**Lb**	**Flooded**	**Tstart**	**Tend**	**Tstart Dewater**	**Tend Dewater**	**Total Quantity**	**Total Cost**	**Pump Rate**
1	8	1	0	0	1	300	1	9.39	42.94	42.94	137.54	225,736	22,573,600	377.13
25	4	1	0	0	1	250	1	6.21	31.57	31.57	147.02	213,160	21,316,047	377.13
9	5	1	0	0	1	175	1	1.10	15.87	15.87	164.80	207,677	20,767,704	56.47
3	2	1	0	0	1	375	1	15.13	67.17	67.17	122.94	239,744	23,974,400	56.47
30	2	1	0	0	1	350	1	13.55	58.80	58.80	257.35	212,143	21,214,287	56.47
8	1	1	0	0	1	200	1	4.04	23.38	23.38	236.07	197,450	19,745,007	56.47
44	6	1	0	0	1	300	1	11.29	50.92	50.92	149.58	222,071	22,207,111	590.90
43	5	1	0	0	1	425	1	18.96	83.29	83.29	98.62	251,196	25,119,644	56.47
10	7	1	0	0	1	375	1	17.12	75.11	75.11	84.13	227,794	22,779,413	56.47
11	2	1	0	0	1	275	1	7.85	35.91	35.91	125.20	199,055	19,905,541	56.47

Table 5-12 Output to Water Quality Model for Sequence 2

Sequence
8002

Island	Segment	# of Breaches	Lb	Tbreach	Tstart Breach Repair	Tend Breach Repair	Tstart All Repairs	Tend All Repairs	Tstart Dewater	Tend Dewater	Pump Rate
1	0	1	300	1	9.39	41.92	9.39	42.94	42.94	137.54	377.13
1	1	0	0	0	0.00	0.00	34.44	35.47	0.00	0.00	0.00
1	2	0	0	0	0.00	0.00	35.47	36.52	0.00	0.00	0.00
1	3	0	0	0	0.00	0.00	36.52	37.62	0.00	0.00	0.00
1	4	0	0	0	0.00	0.00	37.62	38.76	0.00	0.00	0.00
1	5	0	0	0	0.00	0.00	38.76	39.75	0.00	0.00	0.00
1	6	0	0	0	0.00	0.00	39.75	40.94	0.00	0.00	0.00
1	7	0	0	0	0.00	0.00	40.94	41.81	0.00	0.00	0.00
1	8	1	300	1	9.39	41.92	9.39	42.94	0.00	0.00	0.00
25	0	1	250	1	6.21	31.57	6.21	31.57	31.57	147.02	377.13
25	1	0	0	0	0.00	0.00	17.84	18.85	0.00	0.00	0.00
25	2	0	0	0	0.00	0.00	18.85	19.99	0.00	0.00	0.00
25	3	0	0	0	0.00	0.00	19.99	20.98	0.00	0.00	0.00
25	4	1	250	1	6.21	31.57	6.21	31.57	0.00	0.00	0.00
25	5	0	0	0	0.00	0.00	22.00	23.03	0.00	0.00	0.00
25	6	0	0	0	0.00	0.00	23.03	24.14	0.00	0.00	0.00
25	7	0	0	0	0.00	0.00	24.14	25.37	0.00	0.00	0.00
25	8	0	0	0	0.00	0.00	25.37	26.53	0.00	0.00	0.00
9	0	1	175	1	1.90	15.87	1.10	15.87	15.87	164.80	56.47
9	1	0	0	0	0.00	0.00	1.10	2.24	0.00	0.00	0.00
9	2	0	0	0	0.00	0.00	2.24	3.35	0.00	0.00	0.00
9	3	0	0	0	0.00	0.00	3.35	4.55	0.00	0.00	0.00
9	4	0	0	0	0.00	0.00	4.55	5.52	0.00	0.00	0.00
9	5	1	175	1	1.90	15.87	1.90	15.87	0.00	0.00	0.00
9	6	0	0	0	0.00	0.00	6.56	7.79	0.00	0.00	0.00
9	7	0	0	0	0.00	0.00	7.79	8.85	0.00	0.00	0.00
9	8	0	0	0	0.00	0.00	8.85	9.90	0.00	0.00	0.00
3	0	1	375	1	15.13	62.68	15.13	67.17	67.17	122.94	56.47
3	1	0	0	0	0.00	0.00	58.80	59.75	0.00	0.00	0.00
3	2	1	375	1	15.13	62.68	15.13	62.68	0.00	0.00	0.00
3	3	0	0	0	0.00	0.00	60.70	61.78	0.00	0.00	0.00
3	4	0	0	0	0.00	0.00	61.78	63.00	0.00	0.00	0.00
3	5	0	0	0	0.00	0.00	63.00	64.07	0.00	0.00	0.00
3	6	0	0	0	0.00	0.00	64.07	65.30	0.00	0.00	0.00
3	7	0	0	0	0.00	0.00	65.30	66.27	0.00	0.00	0.00
3	8	0	0	0	0.00	0.00	66.27	67.17	0.00	0.00	0.00
30	0	1	350	1	13.55	54.64	13.55	58.80	58.80	257.35	56.47
30	1	0	0	0	0.00	0.00	50.92	51.89	0.00	0.00	0.00
30	2	1	350	1	13.55	54.64	13.55	54.64	0.00	0.00	0.00
30	3	0	0	0	0.00	0.00	52.70	53.67	0.00	0.00	0.00
30	4	0	0	0	0.00	0.00	53.67	54.78	0.00	0.00	0.00
30	5	0	0	0	0.00	0.00	54.78	55.77	0.00	0.00	0.00
30	6	0	0	0	0.00	0.00	55.77	56.72	0.00	0.00	0.00
30	7	0	0	0	0.00	0.00	56.72	57.72	0.00	0.00	0.00
30	8	0	0	0	0.00	0.00	57.72	58.80	0.00	0.00	0.00
8	0	1	200	1	4.04	23.38	4.04	23.38	23.38	236.07	56.47
8	1	1	200	1	4.04	23.38	4.04	23.38	0.00	0.00	0.00
8	2	0	0	0	0.00	0.00	10.86	11.87	0.00	0.00	0.00
8	3	0	0	0	0.00	0.00	11.87	12.79	0.00	0.00	0.00
8	4	0	0	0	0.00	0.00	12.79	13.80	0.00	0.00	0.00
8	5	0	0	0	0.00	0.00	13.80	14.97	0.00	0.00	0.00

Table 5-12 Output to Water Quality Model for Sequence 2

Sequence											
8002											
Island	Segment	# of Breaches	Lb	Tbreach	Tstart Breach Repair	Tend Breach Repair	Tstart All Repairs	Tend All Repairs	Tstart Dewater	Tend Dewater	Pump Rate
8	6	0	0	0	0.00	0.00	14.97	16.14	0.00	0.00	0.00
8	7	0	0	0	0.00	0.00	16.14	16.99	0.00	0.00	0.00
8	8	0	0	0	0.00	0.00	16.99	17.84	0.00	0.00	0.00
44	0	1	300	1	11.29	48.60	11.29	50.92	50.92	149.58	590.90
44	1	0	0	0	0.00	0.00	42.94	44.09	0.00	0.00	0.00
44	2	0	0	0	0.00	0.00	44.09	45.18	0.00	0.00	0.00
44	3	0	0	0	0.00	0.00	45.18	46.08	0.00	0.00	0.00
44	4	0	0	0	0.00	0.00	46.08	47.14	0.00	0.00	0.00
44	5	0	0	0	0.00	0.00	47.14	48.13	0.00	0.00	0.00
44	6	1	300	1	11.29	48.60	11.29	49.11	0.00	0.00	0.00
44	7	0	0	0	0.00	0.00	49.11	49.95	0.00	0.00	0.00
44	8	0	0	0	0.00	0.00	49.95	50.92	0.00	0.00	0.00
43	0	1	425	1	18.96	80.27	18.96	83.29	83.29	98.62	56.47
43	1	0	0	0	0.00	0.00	75.11	76.21	0.00	0.00	0.00
43	2	0	0	0	0.00	0.00	76.21	77.24	0.00	0.00	0.00
43	3	0	0	0	0.00	0.00	77.24	78.09	0.00	0.00	0.00
43	4	0	0	0	0.00	0.00	78.09	79.20	0.00	0.00	0.00
43	5	1	425	1	18.96	80.27	18.96	80.27	0.00	0.00	0.00
43	6	0	0	0	0.00	0.00	79.97	80.98	0.00	0.00	0.00
43	7	0	0	0	0.00	0.00	80.98	82.11	0.00	0.00	0.00
43	8	0	0	0	0.00	0.00	82.11	83.29	0.00	0.00	0.00
10	0	1	375	1	17.12	70.38	17.12	75.11	75.11	84.13	56.47
10	1	0	0	0	0.00	0.00	67.17	68.04	0.00	0.00	0.00
10	2	0	0	0	0.00	0.00	68.04	69.16	0.00	0.00	0.00
10	3	0	0	0	0.00	0.00	69.16	70.13	0.00	0.00	0.00
10	4	0	0	0	0.00	0.00	70.13	71.05	0.00	0.00	0.00
10	5	0	0	0	0.00	0.00	71.05	72.04	0.00	0.00	0.00
10	6	0	0	0	0.00	0.00	72.04	73.18	0.00	0.00	0.00
10	7	1	375	1	17.12	70.38	17.12	74.04	0.00	0.00	0.00
10	8	0	0	0	0.00	0.00	74.04	75.11	0.00	0.00	0.00
11	0	1	275	1	7.85	35.91	7.85	35.91	35.91	125.20	56.47
11	1	0	0	0	0.00	0.00	26.53	27.69	0.00	0.00	0.00
11	2	1	275	1	7.85	35.91	7.85	35.91	0.00	0.00	0.00
11	3	0	0	0	0.00	0.00	28.61	29.51	0.00	0.00	0.00
11	4	0	0	0	0.00	0.00	29.51	30.35	0.00	0.00	0.00
11	5	0	0	0	0.00	0.00	30.35	31.34	0.00	0.00	0.00
11	6	0	0	0	0.00	0.00	31.34	32.21	0.00	0.00	0.00
11	7	0	0	0	0.00	0.00	32.21	33.33	0.00	0.00	0.00
11	8	0	0	0	0.00	0.00	33.33	34.44	0.00	0.00	0.00

5.3 Sequential Output in Text File Format

The main ER&R output will be output sequentially to a text file for all sequences analyzed. Each sequence will start with the sequence ID. The completion of the sequence will be delineated by a line starting with -99999. The output from the ER&R model to the water quality model will similarly be output to a text file which will include a large set of sequences, each identified by its sequence ID and ended by a line starting with -99999.

Figures 5-1 and 5-2 present the appearance of these two text files for the case of two sequences. Figure 5-1 presents the text file that includes the output that was presented in Tables 5-5 and 5-11 for sequences 8001 and 8002, respectively. The column headings are not shown on Figure 5-1, as these do not appear in the sequential text file, but they are identical to the headers in Tables 5-5 and 5-11. Figure 5-2 presents the text file that includes the output that was presented in Tables 5-6 and 5-12 for the two sequences analyzed. The column headings are not shown on Figure 5-2, as these do not appear in the sequential text file, but they are identical to the headers in Tables 5-6 and 5-12.

Figure 5-1 Appearance of Sequential Outputs (for 2 Sequences)

8001	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	127.66	0	372.87	1,427,535	142,753,505	6
3	0	1	0	0	1	300	1	1.50	98.41	98.41	154.17	224,340	22,433,956	56.47
2	0	3	0	0	1	175	1	115.17	130.42	130.42	263.93	31,260	3,125,985	56.47
5	0	2	0	0	1	250	1	98.61	109.79	109.79	208.64	31,305	3,130,453	163.35
7	0	2	1	800	0	0	0	1.40	92.17	0.00	0.00	316,587	31,658,667	0.00
8	0	1	3	1125	0	0	0	1.10	47.09	0.00	0.00	354,000	35,400,000	0.00
10	0	1	2	925	1	100	0	46.25	114.97	0.00	0.00	282,578	28,257,778	0.00
20	0	2	1	600	2	375	1	98.51	127.66	127.66	372.87	187,467	18,746,667	56.47
-99999	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8002	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	58.80	0	257.35	2,196,028	219,602,756	57
1	8	1	0	0	1	300	1	9.39	42.94	42.94	137.54	225,736	22,573,600	377.13
25	4	1	0	0	1	250	1	6.21	31.57	31.57	147.02	213,160	21,316,047	377.13
9	5	1	0	0	1	175	1	1.10	15.87	15.87	164.80	207,677	20,767,704	56.47
3	2	1	0	0	1	375	1	15.13	67.17	67.17	122.94	239,744	23,974,400	56.47
30	2	1	0	0	1	350	1	13.55	58.80	58.80	257.35	212,143	21,214,287	56.47
8	1	1	0	0	1	200	1	4.04	23.38	23.38	236.07	197,450	19,745,007	56.47
44	6	1	0	0	1	300	1	11.29	50.92	50.92	149.58	222,071	22,207,111	590.90
43	5	1	0	0	1	425	1	18.96	83.29	83.29	98.62	251,196	25,119,644	56.47
10	7	1	0	0	1	375	1	17.12	75.11	75.11	84.13	227,794	22,779,413	56.47
11	2	1	0	0	1	275	1	7.85	35.91	35.91	125.20	199,055	19,905,541	56.47
-99999	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 5-2 Appearance of Sequential Outputs to Water Quality Module (for 2 Sequences)

	0	0	0	0	0	0	0	0	0	0	0
3	0	1	300	1	46.15	98.41	1.50	98.41	98.41	154.17	56.47
3	1	0	0	0	0.00	0.00	1.50	2.45	0.00	0.00	0.00
3	2	0	0	0	0.00	0.00	45.45	46.47	0.00	0.00	0.00
3	3	0	0	0	0.00	0.00	46.47	47.55	0.00	0.00	0.00
3	4	0	0	0	0.00	0.00	47.55	48.77	0.00	0.00	0.00
3	5	0	0	0	0.00	0.00	48.77	49.85	0.00	0.00	0.00
3	6	0	0	0	0.00	0.00	49.85	51.07	0.00	0.00	0.00
3	7	0	0	0	0.00	0.00	51.07	52.04	0.00	0.00	0.00
3	8	1	300	1	46.15	98.41	46.15	98.41	0.00	0.00	0.00
2	0	1	175	1	115.17	130.42	115.17	130.42	130.42	263.93	56.47
2	1	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	2	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	3	1	175	1	115.17	130.42	115.17	130.42	0.00	0.00	0.00
2	4	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	5	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	6	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	7	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	8	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	0	1	250	1	98.61	109.79	98.61	109.79	109.79	208.64	163.35
5	1	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	2	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	3	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	4	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	5	1	250	1	98.61	109.79	98.61	109.79	0.00	0.00	0.00
5	6	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	7	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	8	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	0	2	375	1	109.79	124.66	98.51	127.66	127.66	372.87	56.47
20	1	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	2	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	3	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	4	1	150	1	109.79	116.11	109.79	116.11	0.00	0.00	0.00
20	5	1	225	1	116.11	124.66	116.11	124.66	0.00	0.00	0.00
20	6	0	0	0	0.00	0.00	98.51	127.66	0.00	0.00	0.00
20	7	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	8	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
-99999	0	0	0	0	0	0	0	0	0	0	0
8002	0	0	0	0	0	0	0	0	0	0	0
1	0	1	300	1	9.39	41.92	9.39	42.94	42.94	137.54	377.13
1	1	0	0	0	0.00	0.00	34.44	35.47	0.00	0.00	0.00
1	2	0	0	0	0.00	0.00	35.47	36.52	0.00	0.00	0.00
1	3	0	0	0	0.00	0.00	36.52	37.62	0.00	0.00	0.00
1	4	0	0	0	0.00	0.00	37.62	38.76	0.00	0.00	0.00
1	5	0	0	0	0.00	0.00	38.76	39.75	0.00	0.00	0.00
1	6	0	0	0	0.00	0.00	39.75	40.94	0.00	0.00	0.00
1	7	0	0	0	0.00	0.00	40.94	41.81	0.00	0.00	0.00
1	8	1	300	1	9.39	41.92	9.39	42.94	0.00	0.00	0.00
25	0	1	250	1	6.21	31.57	6.21	31.57	31.57	147.02	377.13

Figure 5-2 Appearance of Sequential Outputs to Water Quality Module (for 2 Sequences)

25	1	0	0	0	0.00	0.00	17.84	18.85	0.00	0.00	0.00
25	2	0	0	0	0.00	0.00	18.85	19.99	0.00	0.00	0.00
25	3	0	0	0	0.00	0.00	19.99	20.98	0.00	0.00	0.00
25	4	1	250	1	6.21	31.57	6.21	31.57	0.00	0.00	0.00
25	5	0	0	0	0.00	0.00	22.00	23.03	0.00	0.00	0.00
25	6	0	0	0	0.00	0.00	23.03	24.14	0.00	0.00	0.00
25	7	0	0	0	0.00	0.00	24.14	25.37	0.00	0.00	0.00
25	8	0	0	0	0.00	0.00	25.37	26.53	0.00	0.00	0.00
9	0	1	175	1	1.90	15.87	1.10	15.87	15.87	164.80	56.47
9	1	0	0	0	0.00	0.00	1.10	2.24	0.00	0.00	0.00
9	2	0	0	0	0.00	0.00	2.24	3.35	0.00	0.00	0.00
9	3	0	0	0	0.00	0.00	3.35	4.55	0.00	0.00	0.00
9	4	0	0	0	0.00	0.00	4.55	5.52	0.00	0.00	0.00
9	5	1	175	1	1.90	15.87	1.90	15.87	0.00	0.00	0.00
9	6	0	0	0	0.00	0.00	6.56	7.79	0.00	0.00	0.00
9	7	0	0	0	0.00	0.00	7.79	8.85	0.00	0.00	0.00
9	8	0	0	0	0.00	0.00	8.85	9.90	0.00	0.00	0.00
3	0	1	375	1	15.13	62.68	15.13	67.17	67.17	122.94	56.47
3	1	0	0	0	0.00	0.00	58.80	59.75	0.00	0.00	0.00
3	2	1	375	1	15.13	62.68	15.13	62.68	0.00	0.00	0.00
3	3	0	0	0	0.00	0.00	60.70	61.78	0.00	0.00	0.00
3	4	0	0	0	0.00	0.00	61.78	63.00	0.00	0.00	0.00
3	5	0	0	0	0.00	0.00	63.00	64.07	0.00	0.00	0.00
3	6	0	0	0	0.00	0.00	64.07	65.30	0.00	0.00	0.00
3	7	0	0	0	0.00	0.00	65.30	66.27	0.00	0.00	0.00
3	8	0	0	0	0.00	0.00	66.27	67.17	0.00	0.00	0.00
30	0	1	350	1	13.55	54.64	13.55	58.80	58.80	257.35	56.47
30	1	0	0	0	0.00	0.00	50.92	51.89	0.00	0.00	0.00
30	2	1	350	1	13.55	54.64	13.55	54.64	0.00	0.00	0.00
30	3	0	0	0	0.00	0.00	52.70	53.67	0.00	0.00	0.00
30	4	0	0	0	0.00	0.00	53.67	54.78	0.00	0.00	0.00
30	5	0	0	0	0.00	0.00	54.78	55.77	0.00	0.00	0.00
30	6	0	0	0	0.00	0.00	55.77	56.72	0.00	0.00	0.00
30	7	0	0	0	0.00	0.00	56.72	57.72	0.00	0.00	0.00
30	8	0	0	0	0.00	0.00	57.72	58.80	0.00	0.00	0.00
8	0	1	200	1	4.04	23.38	4.04	23.38	23.38	236.07	56.47
8	1	1	200	1	4.04	23.38	4.04	23.38	0.00	0.00	0.00
8	2	0	0	0	0.00	0.00	10.86	11.87	0.00	0.00	0.00
8	3	0	0	0	0.00	0.00	11.87	12.79	0.00	0.00	0.00
8	4	0	0	0	0.00	0.00	12.79	13.80	0.00	0.00	0.00
8	5	0	0	0	0.00	0.00	13.80	14.97	0.00	0.00	0.00
8	6	0	0	0	0.00	0.00	14.97	16.14	0.00	0.00	0.00
8	7	0	0	0	0.00	0.00	16.14	16.99	0.00	0.00	0.00
8	8	0	0	0	0.00	0.00	16.99	17.84	0.00	0.00	0.00
44	0	1	300	1	11.29	48.60	11.29	50.92	50.92	149.58	590.90
44	1	0	0	0	0.00	0.00	42.94	44.09	0.00	0.00	0.00
44	2	0	0	0	0.00	0.00	44.09	45.18	0.00	0.00	0.00
44	3	0	0	0	0.00	0.00	45.18	46.08	0.00	0.00	0.00
44	4	0	0	0	0.00	0.00	46.08	47.14	0.00	0.00	0.00
44	5	0	0	0	0.00	0.00	47.14	48.13	0.00	0.00	0.00

Figure 5-2 Appearance of Sequential Outputs to Water Quality Module (for 2 Sequences)

44	6	1	300	1	11.29	48.60	11.29	49.11	0.00	0.00	0.00
44	7	0	0	0	0.00	0.00	49.11	49.95	0.00	0.00	0.00
44	8	0	0	0	0.00	0.00	49.95	50.92	0.00	0.00	0.00
43	0	1	425	1	18.96	80.27	18.96	83.29	83.29	98.62	56.47
43	1	0	0	0	0.00	0.00	75.11	76.21	0.00	0.00	0.00
43	2	0	0	0	0.00	0.00	76.21	77.24	0.00	0.00	0.00
43	3	0	0	0	0.00	0.00	77.24	78.09	0.00	0.00	0.00
43	4	0	0	0	0.00	0.00	78.09	79.20	0.00	0.00	0.00
43	5	1	425	1	18.96	80.27	18.96	80.27	0.00	0.00	0.00
43	6	0	0	0	0.00	0.00	79.97	80.98	0.00	0.00	0.00
43	7	0	0	0	0.00	0.00	80.98	82.11	0.00	0.00	0.00
43	8	0	0	0	0.00	0.00	82.11	83.29	0.00	0.00	0.00
10	0	1	375	1	17.12	70.38	17.12	75.11	75.11	84.13	56.47
10	1	0	0	0	0.00	0.00	67.17	68.04	0.00	0.00	0.00
10	2	0	0	0	0.00	0.00	68.04	69.16	0.00	0.00	0.00
10	3	0	0	0	0.00	0.00	69.16	70.13	0.00	0.00	0.00
10	4	0	0	0	0.00	0.00	70.13	71.05	0.00	0.00	0.00
10	5	0	0	0	0.00	0.00	71.05	72.04	0.00	0.00	0.00
10	6	0	0	0	0.00	0.00	72.04	73.18	0.00	0.00	0.00
10	7	1	375	1	17.12	70.38	17.12	74.04	0.00	0.00	0.00
10	8	0	0	0	0.00	0.00	74.04	75.11	0.00	0.00	0.00
11	0	1	275	1	7.85	35.91	7.85	35.91	35.91	125.20	56.47
11	1	0	0	0	0.00	0.00	26.53	27.69	0.00	0.00	0.00
11	2	1	275	1	7.85	35.91	7.85	35.91	0.00	0.00	0.00
11	3	0	0	0	0.00	0.00	28.61	29.51	0.00	0.00	0.00
11	4	0	0	0	0.00	0.00	29.51	30.35	0.00	0.00	0.00
11	5	0	0	0	0.00	0.00	30.35	31.34	0.00	0.00	0.00
11	6	0	0	0	0.00	0.00	31.34	32.21	0.00	0.00	0.00
11	7	0	0	0	0.00	0.00	32.21	33.33	0.00	0.00	0.00
11	8	0	0	0	0.00	0.00	33.33	34.44	0.00	0.00	0.00
-99999	0	0	0	0	0	0	0	0	0	0	0

Appendix A

Development of Wind Wave Erosion Parametric Equations

The erosion curve (time versus erosion) is specifically defined for each island sector. The erosion curves are developed for groups of island sectors that have similar levee geometry and material, fetch and exposure. The seasonal (2 seasons) curves will be developed by separate analysis outside of the main risk assessment and, once developed, will be included in the ER&R module.

Episodic events do not need to be explicitly included in the ER&R module for purposes of secondary damage (erosion) computation. This removes unnecessary complexity from the model, by eliminating a need for interface with the wind hazard module. Each erosion curve, or parametric equation, is developed by incorporating seasonal conditions and episodic events into the analysis.

Separate analysis that we have carried out indicates that both seasonal and episodic events contribute to levee erosion. The analysis also demonstrates that, over time, the waves generated by the seasonal winds are the more significant contributor to levee interior slope erosion. Since the episodic events are not significant contributors to levee interior slope erosion, the problem can be simplified significantly by treating these events in a separate analysis and incorporating their effect into the erosion curves rather than treating them as separate events in the ER&R model. Because of their lesser importance in the computation of ongoing damage on already flooded islands, they are not necessarily required in the ER&R module.

The development of the erosion curves, or parametric equations, was carried out outside of the ER&R module. Its main objective is to develop a set of erosion curves, or parametric equations, which will be input into the ER&R module to accumulate erosion damage over time as repairs progress.

1. Develop a relationship between levee erosion rate and wind wave height, which includes uncertainty.
2. Analyze historical wind data and develop wind roses (for long-term erosion calculation) and extreme wind events (return period wind speed and duration, for episodic wind wave erosion calculation) for each of the 8 directions (N,S,E,W,NW,NE,SW,SE). This work is to be carried out by PWA. The available wind stations include Sacramento Airport, Stockton Airport, Bethel Island (Bay Area Air Quality Management District station), Pittsburg Power Plant or Port Chicago (NOAA station). The entire Delta area can be divided into four regions, each of which will be represented by one of the wind stations.
3. Generate a random wind time history for a period of time that covers the period of repair (say 10 years), based on results from 2).
4. Calculate wind waves using results from 3), for a number of fetch distances.

5. For each fetch distance, calculate cumulative levee erosion over time based on results from 4) and 1) along each individual wind direction. For each wind direction the entire perimeter length of the opposing island sector will be assumed to be subject to erosion.
6. repeat 3), 4) and 5) multiple times (say 100), and develop averaged levee erosion over time with the 1-standard deviation upper bound and lower bound as well, for each wind direction and for each of the fetch distances specified above.

The analyses will be carried out on 1 or 2 typical levee cross sections. Levee material is assumed to be compacted silty sand. The result of the set of analyses will be a database that can be used within the ER&R module.

The underlying assumption is that wind-driven waves will be fully developed within 1 hour.

Relationship Between Levee Erosion Rate And Wind Wave Height

Estimating wind-wave induced damage to flooded island levees in the Delta requires a means of correlating wave heights to rates of erosion. Many studies have investigated levee or shoreline erosion due to waves or other scour processes (Elci et al. 2002; Foda et al. 1999; Hanson and Cook 2006; Hanson and Hunt 1999; Seed et al. 2006). Erosion processes are complex and involve numerous dependencies; thus, many investigations utilize approaches that require calibration to site-specific hydraulic boundary stresses, soil properties and other parameters such as vegetation. Because no experimental or field erodibility data was available to this study, a range of approaches and assumptions was utilized in attempt to “book-end” or bracket the likely expected envelope of erosion.

The stress-based detachment equation (also referred to as excess stress equation) was used to calculate the time rate of erosion under wave stresses (Hanson and Cook 2006; Hanson and Hunt 1999). The equation states that the erosion rate is a function of a soil detachment coefficient, a wind/wave-induced hydraulic boundary stress, and a critical soil stress required to initiate material detachment

$$\varepsilon = k_d (\tau - \tau_c) \qquad (1)$$

where:

ε = erosion rate in volume per unit area per unit time (ft/hr)
k_d = detachment rate coefficient, a soil material property (ft^3/lb-hr)
τ = hydraulically applied boundary stress (lb/ft^2)
τ_c = critical soil shear stress for erosion, a soil material property (lb/ft^2).

The hydraulic boundary stress, τ, in Equation (1) was calculated using a boundary shear stress formulation, whereby the boundary stress is a function of wave height under pure wave environments (Fredsoe 1981 in DHI 1996). The formulation states:

$$\tau = \tfrac{1}{2} \rho f_w U^2_b \qquad (2)$$

where:

ρ = density of the fluid (lb/ft^3)
f_w = wave friction factor (unitless)

U_b = horizontal mean orbital wave velocity at water-soil interface (ft/s)

The wave friction factor is an empirically based function of the mean orbital motion at the bed, wave properties including the wave height and period, and a roughness-friction factor. The orbital wave velocity, U_b, is dependent on the significant wave height, the wave period, and the water depth.

Because the boundary shear stress approximation is generally suitable for slower erosion of softer bottom sediments like those of a lake or river bed, it may underestimate erosion of shorelines or levee embankments that are often under-cut and incised, eroding irregularly over time. To consider the eroding forces of waves directly impacting a sloped levee surface, a wave force method was also utilized to approximate the erosive shear stress (USACE 2001). This method is a physically based approach to approximate horizontal forces of shallow water waves. This alternative procedure also relates wave height to hydraulic bed shear stress by integrating the wave force over the length of the wave to calculate an average erosive force per unit area of levee in the direction of the levee slope.

The soil dependent variables in Equation (1) are τ_c and k_d. These are used to represent the range of parameters that affect soil erodibility:

- Soil gradation
- Compaction
- Water content
- Dry density

In erosion modeling studies, the values of these soil parameters range widely. Sands and clays can show variations of several orders of magnitude. For the purposes of this investigation, levee material is assumed to be a relatively firm soil that is predominately clay with some silt. For soils of this type, the parameters k_d and τ_c can range as shown in Table A-1.

Table A-1 Soil Erodibility Parameter Ranges

Parameter	Lower Limit	Upper Limit
Detachment Coefficient, k_d	0.1cm3/N-s (1.6E-5 ft3/lb-s)	0.3 cm3/N-s (4.7E-5 ft3/lb-s)
Critical Soil Stress, τ_c	5 Pa (0.11 lb/ft2)	12 Pa (0.25 lb/ft2)

Source: Hanson and Cook 1999; Hanson and Hunt 2006.

The resulting erosion calculations are plotted in Figure A-1. The discrete points, "erosion samples" (blue dots), were calculated by the two different wave stress methods and by using the upper and lower limits of the soil parameters. Based on these discrete erosion points, an upper and lower envelope was defined by calculating the plus one and minus one standard deviation about the mean erosion rate. The shaded region in Figure A-1 is the envelope of likely erosion rates under varying wave conditions.

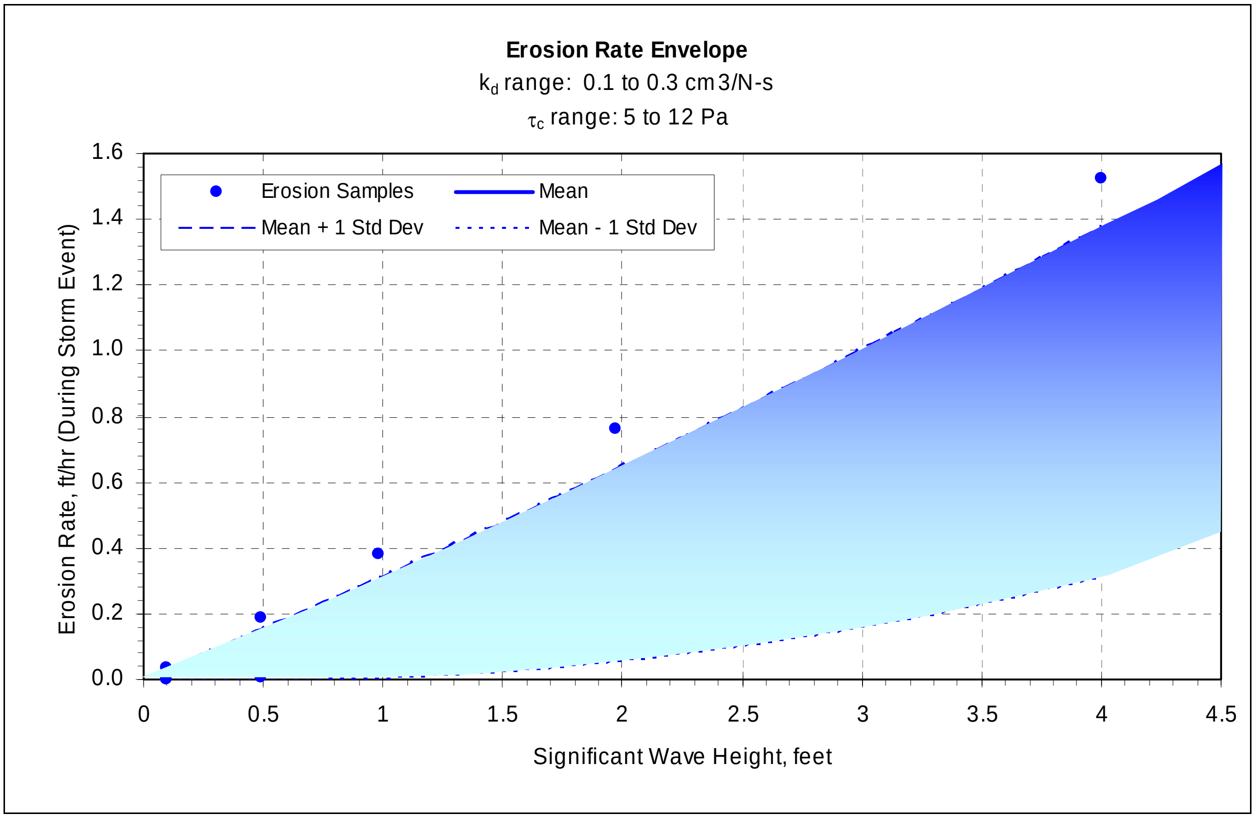

Figure A-1 Erosion Rate Envelope

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